PART 6

Important players and driving forces for science and innovative development

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THE POLITICS OF TECHNOLOGICAL INNOVATION
The case of U.S. solar industry
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Introduction
Global economic and per capita income growth will lead to increasing world energy needs and emissions of greenhouse gases that, in turn, will accelerate and intensify the consequences of climate change. Research and development of renewable energy technologies are a matter of global concern and interest because deployment of these technologies can ameliorate or break the link between economic development and local, regional, and global environmental damage. Furthermore, renewable energy sources can provide the quantity, form, and quality of energy needed to meet demands for economic growth and can be sustainable if they are based on forms of solar energy that are replenished on a timescale on the order of a human lifespan. If so done, there will be minimal net increase in greenhouse gas emissions and further disruption of the radiative energy balance of the earth’s atmosphere. The use of renewable energy will allow economic development and mitigation of climate change to proceed in synergy rather than in opposition.

Any state seeking to meet the twin challenges posed by economic development and climate change must decide how to guide and support the innovation process involving renewable energy technologies. The content of such decisions is shaped by two primary factors, the nature of the technologies themselves that define possibilities and options and the political decision making system that includes institutional structures, the values of decision makers, and the power of various organized groups. Thus a study of how the U.S. has attempted to promote solar technologies provides a useful case that permits us to analyze the relationship between technological innovation and the ways in which a government functions influences this process.

The nature of solar energy technologies
Renewable energy can be defined in the broadest sense as any form of primary energy that is derived directly or indirectly from the sun. In this sense, renewable energy sources such as biomass,
hydropower, and wind are different forms of solar energy. The most familiar forms of energy used around the globe, such as wood, oil, gas, and coal are embodied forms of solar energy that have been gathered, transformed, and stored by natural processes. Emissions of greenhouse gases from converting and using energy resources become a global concern when the rates of conversion of stored solar energy to more usable forms (heat, electricity, fuels, and chemicals) far exceed those of formation.¹

The surface of the earth receives about 1 kW/m² of solar energy at peak intensity, and there is no constraint of resource availability; in one hour, the earth receives more energy from the sun than the total annual global consumption of energy.² Solar panels and other collection devices are used to capture the incoming solar energy and convert this energy into usable electricity. Electricity from solar energy can also be used to produce hydrogen, which can be used as a fuel (in place of gasoline) in zero-emission fuel cell engines or to store the electricity and help overcome the intermittency of solar energy. Electricity and hydrogen are particularly valuable energy carriers because they are interchangeable.³

Electricity from renewable resources can be generated by large facilities such as wind farms and concentrating solar energy plants. Photovoltaic (PV) technologies offer a direct path to renewable and sustainable electricity generation. Among solar energy technologies, PV systems possess typical characteristics, such as zero emissions and modularity, but also those that are unique, such as no moving parts, fluids, or gases; high power-to-weight ratio; and instantaneous output.⁴ Solar panels are modular and can generate electricity for an individual building, for a village, or for larger communities. Hence, policies that lead the development and widespread use of this technology will have very beneficial effects on the environment and on climate change.

Small solar systems can be located to take advantage of locally available solar energy resources and adjusted to best fit the local environmental and energy situation. A distributed energy system of interconnected groups of solar panels, for example, results in a much more robust power generation system that is less vulnerable to disruptions whether they are due to natural or man-made disasters.⁵ Such decentralization clearly offers significant technological advantages, especially if coordinated on a national level but doing so requires careful coordination between local political entities and a central authority, a condition that may often be difficult to meet, especially when the former enjoys a high degree of autonomy as is the case in the U.S. as well as in other states with federal systems.

Although the widespread deployment of solar technologies will have multiple and synergistic economic, societal, political, and environmental benefits, nations whether industrialized or developing will not be able to realize such benefits unless they act individually and collectively to address a host of policy issues, including those that directly or indirectly affect technological innovation. Photovoltaic technologies also present a number of policy issues involving technology R&D and innovation.

Hence, in this chapter we analyze the choices that governments, primarily the U.S., have made in seeking to promote the development and diffusion of this specific subset of solar energy technology. We do so in order to answer such questions as 1) what policies did the U.S. adopt and how effective were they? 2) why did the U.S. adopt such policies? And, 3) what lessons emerge on how governments seeking to promote technological innovation should proceed? In order to do so we shall consider in detail the specific ways in which U.S. policy has evolved and the factors that have shaped its evolution. However, to understand the policy issues, it is necessary to consider the ways in which technological innovation occurs and the role of national policies therein.
The nature of technological innovation and national policies

If the dream of solar energy is to be realized, technological innovations are required, but doing so successfully is no easy matter. Though governments everywhere seek to develop policies to promote technological innovation, examples of policy failures can easily be found throughout the globe. The problem is that innovation is a complex activity that involves a high degree of uncertainty.

In addition to the political issues that complicate the difficulties of devising and implementing effective policies in any technological sector, conceptual issues further complicate this task. This complexity is reflected in the fact that scholars disagree even on the meaning of terms as well as on the conceptualization of the process. Though there is general agreement that it involves a number of stages, no consensus exists on the number of stages or on the nature and extent of the feedback loops that are involved. The simplest categorization posits a linear model with three stages—Research and Development, Commercialization, and Diffusion. These stages are also known as R&D, Market Formation, and Diffusion. A slightly more elaborate model identifies four stages—Research, Development, Demonstration, and Commercialization.

In Auerswald and Branscomb (2003), a more sophisticated model identifies a five stage process with various feedback loops. Whatever the conceptualization, each stage requires various inputs, and, hopefully, yields an output that, at the end of the process, has led to a commercially viable product. Scholars also agree that a simple linear process does not capture the complexities of the innovation process for it is necessary to incorporate feedback loops and interactions among the stages. A sophisticated version of this type is developed by Gallagher et al. (2012: 140) for the energy sector.

Not only is there agreement that the process does not flow smoothly but many scholars have labeled the stage that lies between a successful output from basic research and its successful commercialization as the “valley of death.” As the name vividly implies, this is the final resting place for many innovations. Though effective government policies can help to overcome this formidable barrier, whether and how a government should be involved is often a very controversial ideological issue whose outcome will determine to a significant degree whether such policies will be adopted. Conceptual problems compound this difficulty for it is not at all clear how the process of technological innovation can best be operationalized. Beard et al. (2009), for example, seeking to analyze the “valley of death” phenomenon, found it necessary to limit the innovation process to three stages—basic research, “the valley of death,” and diffusion.

It is, however, also possible to conceptualize this complex overall process with its stages and feedback loops through two simple analytical models. The first, a “discovery push” model, stresses the importance of research and development activities that are focused to a greater or lesser degree on specific technologies, some of which may be pursued by scientists with no clear market in mind yet often turn out, as in the case of the laser, to have profound impacts on national and international economies and societies. Such research is often conducted in university laboratories. Governments, however, also frequently play an important role in this model, sponsoring research and development activities that are focused on a specific perceived need, even creating R&D organizations for this purpose (Szyliowicz 1981). The establishment of the National Renewable Energy Laboratory by the U.S. government is a prime example. The second is the “demand-pull” model, most often characteristic of industrial research and development activities where a company’s sales force has identified a potentially profitable gap that remains to be filled and its research and development section set to work to develop a suitable product or process. Recently, however, the demand side has received increased attention as experts have identified various obstacles at the last stage(s) of the innovation process that prevent the wide
diffusion of technologies that have escaped the “valley of death.” Accordingly various policies
designed to eliminate or minimize the impact of the barriers that limit market introduction and
diffusion and to increase the demand for a new product have been proposed (OECD 2011).

Choosing and implementing an appropriate set of policies is clearly a complex issue though it is important to recognize that scholars have established certain important points. First, as noted above, it is essential to recognize that linkages are critical and that success is more likely when government, industry, and academia interact cooperatively. Second, is the importance of recognizing that it is necessary to take a holistic perspective and recognize that even policies in another area can have positive or negative impacts. Thus any government seeking to influence the technological process in a specific sector must pay attention to at least two sets of policies. The first, difficult enough, involves selecting and developing the most appropriate policies to impact the innovation process of a particular technology. The innovation process, however, is also influenced by a range of indirect impacts resulting from policies that have been adopted in other sectors such as, for example, import regulations.

This point is underscored by a recent study performed by two Federal Reserve Bank associates that sought to measure the impact of technology policies on aggregate output over time. They found that government policies designed to support research and development activities by firms were effective only if the tax and regulatory environments were also supportive. Thus, since policies sometimes came into conflict, it is critical to examine both direct and indirect policies to ensure that they are mutually reinforcing rather than negating each other.

Such complexity does not negate the need for such policies as evidenced by the results of a recent study of the sources of innovation in the U.S. It found that large corporations are no longer the major contributors. From 1971 to 2006, the number of awards for innovation won by the 500 largest US firms fell from about 40 to four. And, the proportion of U.S. corporate patents by such traditionally technologically innovating firms such as G.E., Kodak, AT&T, DuPont, G.M., Dow Chemical, 3M, United Technologies, and Ford fell from 10 percent to 4.5 percent during the same period. Furthermore, technological innovations are increasingly federally funded and the result of cooperative interactions made possible by linkages between the private sector, federal laboratories, and academic researchers (Block and Keller 2008). The evidence that public policy has a powerful impact on technological innovation has also been demonstrated by a sophisticated cross national analysis of several OECD countries over a five year period, using patent data, though it found that the impact varies depending upon the policy and the type of technology involved. Specifically, the authors state:

Our empirical results indicate that public policy has had a very significant influence on the development of new technologies in the area of renewable energy. Using the composite policy variable, statistical significance at the 1 percent level is found for all renewable energy sources, except biomass (where it is significant at the 5 percent level). However, the results suggest that instrument choice also matters. With respect to patent activity in renewable energy overall, taxes, obligations and tradable certificates are the only statistically significant policy instruments.

(Johnstone et al. 2008; also see Gallagher et al. 2012: 149ff).

The politics of science and technology policy in the U.S.

The U.S. has for decades adopted various policies to promote technological innovation. In this sector and others, U.S. policies have fluctuated over time but they can essentially be assigned to three major categories. The first, Direct Government Funding of R&D, includes R&D
contracts with private firms, contracts and grants with universities, Intramural R&D conducted in government laboratories, R&D contracts with industry-led consortia or collaborations among two or more of the actors above. The second, Direct or Indirect Support for Commercialization and Production and Indirect Support for Development includes patent protection, R&D tax credits, tax credits or production subsidies for firms bringing new technologies to market, tax credits or rebates for purchasers of new technologies, government procurement, and demonstration projects. The third category involves Support of Learning and Diffusion of Knowledge and Technology. This includes education and training, codification and diffusion of technical knowledge, technical standard setting, industrial or technology extension services, publicity, persuasion, and consumer information (Alic 2002). Which of these tools should be used and to what degree is a question that has always been answered by the nature and functioning of the political system. And, since there is often little agreement beyond the view that governments should create an environment that facilitates technological innovation, the specific policies that have been adopted have always been a function of the nature of the dominant ideology and the distribution of political power at any given time.

Most of the literature dealing with technological innovation, however, is not the work of political scientists so that political considerations are seldom discussed in a way that adequately considers the policy and decision process. The authors of an important detailed study on the Energy Technology Innovation (ETIS), for example, discuss the political dimension as follows:

Actors and institutions strongly affect the ETIS. The roles and importance of different actors and institutions vary among innovation systems, and also change over the lifecycle of an innovation . . . . Typically, for example, as innovation systems increase in maturity, the importance of private actors increases . . . . New energy technologies often face resistance from actors with vested interests in incumbent systems. To build up innovation systems, actors, particularly from non-governmental organizations (NGOs) and industry, can counteract this inertia though political lobbying and advocacy coalitions. Public institutions may also contribute, as in the case of planning agencies advising regional or national governments to develop supporting policies for emerging technologies.

(Gallagher et al. 2012: 143)

Although this discussion identifies some of the key actors, it merely hints at the political nature of the process or the ways in which the structure and functioning of the relevant organizations and the worldviews of their elites shape outcomes. The nature of power relations determines policy choices but those relations are the result of a potent mixture of specific ideas, interests, personalities, and institutional structures. It is therefore necessary to discuss the nature of the U.S. political system because, like any such system, it possesses distinct features and characteristics.

One of these involves an important characteristic of any political system—how power is distributed vertically. Essentially there are two basic patterns. In some the central government monopolizes power, in others, power devolves to regions or states, as is the case in Germany and the U.S. where the individual states have significant latitude in making policy decisions in many areas including energy. California, for example, a leader in environmental protection has often led the way in establishing new environmental standards. It has now committed itself to “reducing of statewide greenhouse gases (GHG) emissions to 1990 levels by 2020 and to 20 percent of 1990 levels by 2025 and providing 33 percent of our electricity demand in 2020 from renewable resources.”7 Policy making at this level, however, is similar to that at the center,
with a variety of actors possessing different ideologies and resources seeking to determine outcomes. This is certainly commonplace in the American system—the case of ethanol in Iowa, discussed in Chapter 20, provides a vivid illustration of this phenomenon.

These forces also operate at the national level of any state. In the U.S., the government’s power is divided among three branches—the judiciary, the executive, and the legislative with its two bodies, the Senate and the House of Representatives. Legislation has to be approved by both bodies and signed by the President. As head of the executive branch, he is the most powerful person in the state but that power is circumscribed not only structurally (for example, he possesses a veto power but it can be over-ridden by a two-thirds vote in the Senate) but also by many political forces.

Herein lies the answers to how and why the “valley of death” discussed above is such a major feature of technological innovation in the U.S., why so many potentially important technologies that have emerged from an earlier stage apparently do not receive adequate funding and thus never make a successful entry into the marketplace. Beard’s research led him to conclude that: “the Valley of Death is a phenomenon that may be a consequence of the US Government focusing its R&D investment activities upon early stage, basic research, with less attention paid to intermediate-stage projects” (Beard et al. 2009: 355). But why is this the case? The answer lies in the nature of the horizontal governance structures that characterize the U.S. political system. A recent study found that the separation of powers prevents the essential coordination required if innovations are to successfully navigate the “valley of death.” As the authors noted, “Today, many of the specifics of energy research, development, and demonstration (RD&D) programs are decided by the Department of Energy (DOE) headquarters while many of the most important deployment incentives are decided in Congress or by federal and state standard-setting agencies” (Anadón et al. 2010: 1). In short, despite its important role in developing and administering energy policies, the DOE may perhaps be considered as “primus inter pares.”

This division of power, where many layers and actors influence technological policy making, clearly complicates any effort to create and implement a strategy that is based on a rational, integrated long term approach. Moreover, the President has the power to shape energy policy and to influence the DOE’s activities, sometimes with unfortunate consequences, as was vividly illustrated by the widely publicized Solyndra affair which also reveals the difficulties that confront the Obama administration (indeed any government) seeking to promote technological innovation.

The nature of the political parties adds additional powerful actors since they are themselves internally divided into various factions over which there is little hierarchical control. Thus, though the policy process is driven by the ideas, aims, and orientation of the government in power, with the President as the key policy maker, the degree to which he is able to actually shape policy is a function of his ability to gain the support of other powerful actors including economic and political interests (Congress and even elements within the bureaucracy) and ultimately the public. Thus the American political system is characterized by frequent conflict as personalities, ideologies, and organizations clash. Under these conditions it is not surprising that business and other interests that naturally seek to influence the policy process are often able to do so very effectively both at the state and the federal level.

One scholar has attempted to bring analytical order to this complexity by building on the concept of “issue networks” and has identified eight “arenas” or groups of primary actors—“legislative,” “executive,” “regulatory,” “academic-professional,” “corporate-managerial,” “judicial,” “labor,” and “public mobilization.” Each has its own power structure, perspectives, interests, and possesses different power and access to the decision making process. The basic technology strategy that leads to a focus on particular kinds of technologies as well as the
technology policies designed to promote the development of a specific area is produced by the interaction of these groups whose perspectives and positions change according to the technology involved (Hamlett 1992). In reality, the process is even more complicated, for these “arenas” contain sub sets of actors who often disagree, as evidenced by the Solyndra case discussed below. And, to understand the role of Congress, it is not only essential to understand such factors as its committee system and their jurisdictions, the role of the filibuster in the Senate, the power of private sector lobbyists and of public interest groups, but the ways in which Senate and House members frame the issue as well.

The area of science and technology clearly reflects this general pattern. It is characterized by sharp ideological divisions, between and to some degree within the political parties, and attempts by powerful business groups and non-governmental organizations to influence policy. Of particular concern is a key issue—should the U.S. government play an active role at this stage of the innovation process or should it permit only market forces to operate. The outcome of such a debate has important implications because each ideological position contains very different perspectives, each of which inexorably leads to particular policies that will profoundly affect the character of future technological development.

A large majority of the Republican Party’s Congressional delegation and its supporters argue that national government action should be limited, that it should act only to the extent that its policies facilitate the work of the private sector since that is where most innovations originate. Its 2012 platform articulated this perspective in no uncertain terms:10

We look to government—local, State, and federal—for the things government must do, but we believe those duties can be carried out more efficiently and at less cost. For all other activities, we look to the private sector; for the American people’s resourcefulness, productivity, innovation, fiscal responsibility, and citizen-leadership have always been the true foundation of our national greatness. For much of the last century, an opposing view has dominated public policy where we have witnessed the expansion, centralization, and bureaucracy in an entitlement society. Government has lumbered on, stifling innovation, with no incentive for fundamental change.

If such an ideology prevails, then the basis is laid for the emergence of a wider range of technologies than would otherwise be the case. In other words, action by the national government should be limited, it should act only to the extent that its policies facilitate the work of the private sector since that is where most innovations originate. It should, at most, promote basic research and help ensure that an adequate supply of trained scientists and technologists is available but it should exercise great care to adopt only policies that do not hinder the private sector’s innate ability to innovate; it should not interfere in any way in the operation of free markets since by doing so, it will hinder the creation and diffusion of new technologies by erecting barriers and distorting the efficient allocation of resources (Block and Keller 2008: 1–2).

Proponents of an active policy argue that markets do not always work efficiently and point to the important contributions that government policies have historically made to the emergence of technological innovations in defense and other sectors. Accordingly, they argue:11

If networks involving government research and development (R&D) programs and scientific and technical experts have been at the heart of the innovation economy, then policies that limit or even roll back government involvement in innovation are counterproductive. Instead, effective technology policies would require active
government support of targeted R&D programs and collaborative mechanisms that support innovation.

The key, in their view is to create an environment that links universities, the private sector, and the government into a dynamic and mutually reinforcing relationship.

This ideological perspective is shared by many in the Democratic Party, which is committed to the view that the government must play an active role in promoting technological innovation. Its 2008 platform, for example, stated that it would “fast-track investment of billions of dollars over the next ten years to establish a green energy sector that will create up to five million jobs,” and said the party was “committed to getting at least 25 percent of our electricity from renewable sources by 2025” (Malakov and Sachdev 2012). Such a commitment highlights the relationship between particular ideologies and the nature and scope of technological development.

Upon coming to power, President Obama attempted to develop and implement such a policy because of the state of the economy and his recognition that new technologies lead to economic growth. His policy has also been motivated by the growing awareness of the threat posed by climate change though many powerful actors continue to argue that human activity is not responsible for the changes that are evidently taking place. Such arguments are widely held by many Republicans and continually advanced by well financed groups who advance such arguments through all possible channels including the distribution of such free books (including a DVD) as *The Mad, Mad, Mad World of Climatism: Mankind and climate change mania*. It argues that “contrary to what our newspapers, our professors, or our political leader [my emphasis] tells us, global warming is natural and cars are innocent.” Indeed President Obama is explicitly listed, along with Angela Merkel and David Cameron as being one of the “World Leaders Captured by Climatism” (Goreham 2013: 10–11).

President Obama has clearly earned such a designation, and has often stressed the need to promote the development of renewable energy. Soon after coming to power, his administration published a formal policy statement on this topic (2009) and, in February 2011 issued an update. Entitled “A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality Jobs,” it emphasized the potential of solar energy and reflects an awareness of the need for an active government role, albeit one that promotes and does not hinder the effective operation of the market. It stated:

A modern, practical approach recognizes both the need for fundamental support and the hazards of overzealous government intervention. The government should make sure individuals and businesses have the tools and support to take risks and innovate, but should not dictate what risks they take.

It focused on three policy areas: 1) enhancing investments in fundamental research (with 3 percent of GDP as the goal), education, and infrastructure in science and technology, 2) increasing market based innovation by creating an entrepreneurial environment in both the private and public sector, supported by exports and capital markers, and 3) promoting national priorities in such areas as clean energy through government action when market failures occur.12

Although the President has outlined a specific strategy that fits clearly into the three major categories discussed above that have traditionally guided U.S. technology policy—Direct Government Funding of R&D, Direct or Indirect Support for Commercialization and Production and Indirect Support for Development and Support of Learning and Diffusion of Knowledge and Technology, its successful implementation requires the participation of many
actors, notably Congress which wields considerable power in establishing technological and other policies through its ability to create new programs, exercise legislative oversight, and provide funding. Thus, the President can present a budget that incorporates increases for energy R&D but it is Congress that will determine how much will actually be allocated and under what conditions. Similarly, the President can propose new standards and regulations but these may require Congressional assent.

Under these circumstances, two points deserve to be emphasized, one theoretical, the other practical. First, the process of technological innovation cannot be separated from its political context because the technology that emerges in the market place is one that has found enough political support to help it overcome particular barriers in the innovation process. Second, it is by no means clear that Obama’s innovation strategy will be implemented as he has outlined, given the nature of the American political system. An important variable that mitigates against success is the fact that the Republican Party controls the House of Representatives and an overwhelming majority of its members believe (despite the evidence to the contrary) that an active government policy is inherently counterproductive as it creates barriers to innovation and to the operation of the market that, left alone, is the most efficient producer of successful innovations.

Even so, the President has, because of his administrative responsibilities, a wide set of tools that essentially give him the power to create and enforce what amount to new laws. These include issuing Executive Orders, Presidential Proclamations, Signing Statements, and Regulatory Reviews. Thus, though a partisan deadlock between Democrats and Republicans may aggravate the structural separation of powers and create legislative paralysis that prevents the passage of new legislation, the President can still wield great influence over the ways in which technology policy is implemented (Flanagan 2011).

In terms of energy generally and solar energy specifically, such Presidential actions will be targeted largely at The Department of Energy (DOE). It is the major bureaucratic actor in the energy sector and is responsible for a large number of initiatives designed to improve the environment. It is therefore, involved in technology R&D and innovation for photovoltaics.

**U.S. policy towards solar energy: meeting the foreign challenge**

Any consideration of the role of solar energy in the U.S. in coming decades must take into account the activities of international competitors. At this stage, due to limited and inconsistent solar policies, the deployment of solar energy in the U.S. during the past decade has lagged behind that in European and Asian countries, which have instituted stronger policies to promote solar energy and thus pose a continuing challenge to the American effort. The two major players are China and Germany.

Germany’s renewable energy policies were first crafted in the early 1970s. The German strategy has been to promote the development of marketable products, thus creating a new market, domestically and internationally. It has, therefore, sought to foster the deployment of renewable energy (RE) sources, with the Feed-in-Tariff (FiT) being the central approach. Reinforcing the FiT has been an array of additional policies to increase public support for R&D of PV technologies, as well as measures to spur investments by manufacturing plants. Initiated in 2000, the Renewable Energy Sources Act (EEG) applies to electricity generated from RE sources, and established FiT levels for each specific RE source with the FiT levels for PV being the highest. The PV tariffs are paid for a 20-year period, with levels determined based on the type of installation (ground or roof-top) and the kW threshold capacity of the system (30 kW, 100kW,
and 1000 kW). The tariffs are to decrease at a scheduled rate during the specified time period, to account for decreasing costs associated with increased technological innovation. The German government decided to cut the tariff three times during 2010, instead of the scheduled reduction of roughly 9 percent, as system prices were falling much faster in 2009 than originally expected; the total reduction from the 2009 level was approximately 23 percent by the end of 2010. The years 2011 and 2012 also saw stronger decreases, at 24 percent and 15 percent, respectively (Avril et al. 2012: 249–250). The government subsidized this tariff at an average annual cost of €4,270 million from 2003–2009. The EEG was amended in 2004 and 2009 to adapt to changing technologies and market circumstances, in order to ensure the more efficient deployment of RE sources. The 2004 amendment saw an increase in the PV FiT, and the 2009 amendment adjusted the schedule due to the drastic fall in system prices. PV installations increased greatly following both of these changes (Grau et al. 2009: 26–28; Laird and Stefes 2009: 2622–2624). Moreover, one cannot ignore various additional market stimulation measures and investment support policies nor the role of the EU. Despite these efforts, there is a fear in Germany that the FiT and its resulting large PV deployment is creating high costs for German electricity consumers, while also benefiting Chinese manufacturers instead of the development of German industry (Grau et al. 2009: 21).

China’s first major PV policies date back only to 2009 and 2010 when the central government established the Golden Sun Program and some large-scale FiT programs. These were market policies designed to operationalize the medium- and long-term strategy initiated by the National Development and Reform Commission in 2007. The goals of these PV policies are the national deployment of 5 GW of PV electricity installed by 2015, and 20 GW by 2020. While there have also been some PV manufacturing investment incentives and market policies established by city and regional governments, R&D continues to have the smallest budgets at both national and regional levels (Grau et al. 2009: 30–35). However, the amount of government funding for R&D has been expanding for state owned enterprises (SOEs) (Anadón 2012: 3). Accordingly, though China has been able to produce and export large amounts of inexpensive solar panels, there is the concern that a strong domestic innovation capacity is being neglected as many technologies and much manufacturing equipment is being imported from Germany (Grau et al. 2009: 21).

Regardless of the Chinese and German concerns, their policies have had a profound impact on the U.S. whose market share of PV module supply has declined significantly during the past decade, falling from 30 percent of global shipments in 2000 to 6 percent (about 1000 MW) in 2010, a decade in which global shipments grew at a compound annual rate of 53 percent and reached 17 GW in 2010. In 2010, solar energy provided less than 0.1 percent of the electricity demand in the U.S., which is comparable to that provided by nuclear energy in 1960.

In an attempt to develop a long-term, multi-mission national program that will enable the U.S. to regain the technological lead in solar energy, the DOE is implementing the SunShot Initiative. Incorporating both the “discovery push” and “demand pull” approaches to technology innovation, it purposely invokes President Kennedy’s “moon shot,” a policy objective that has become emblematic of a concerted—and successful—effort to achieve a challenge worthy of a great nation. Announced by Secretary of Energy Steven Chu in February 2011, this initiative explicitly recognizes that “America is in a world race to produce cost-effective, quality photovoltaics” and seeks “significant improvements in solar cell efficiency, reliability, and cost [and] to move novel PV devices and systems to pilot production as well as advance market-ready technologies into mass production.” The SunShot initiative will enable the U.S. to achieve these goals by:

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spurring American innovations to reduce the costs of solar energy and re-establish U.S. global leadership in this growing industry. . . . It will boost our economic competitiveness, rebuild our manufacturing industry and help reach the President’s goal of doubling our clean energy in the next 25 years.

If the cost targets are reached, it is estimated that solar energy has the potential to meet roughly 14 percent of electricity demand by 2030 and 27 percent by 2050 in the contiguous U.S. (excluding Alaska and Hawaii).14

Both evolutionary and revolutionary technologies changes will be required to achieve the cost and deployment targets of the initiative. Of the steps in the innovation process, the key findings of the Vision Study focus more on market formation and diffusion than on R&D and demonstration, on an attempt to successfully cross the valley of death. It seeks to do so by attempting to achieve efficiency improvements, material substitutions, and expanded material supplies through “technological advances,” but this advancement may be more difficult than anticipated. The technological pathways to revolutionary improvements in PV technologies are not known today and will require more R&D with a sustained focus on meeting the cost target (Vision Study 2012: xxviii). Acquiring the resources for such activities will, as always, become a political matter whose outcome will be determined by a struggle between various more or less powerful actors.

Sensitivity analyses conducted by the Vision Study reveal the major weakness of this and other initiatives devoted to a particular technology or set of technologies (Vision Study 2012: xxii). The level of solar energy deployment for electricity generation envisioned by the SunShot Initiative is contingent on how aggressively cost reductions for other renewable electricity generation technologies, especially wind, and conventional technologies are pursued and achieved by actors and institutions in both the public and private sectors. At certain price thresholds, which differ among renewable energy technologies, deployment increases non-linearly with cost reductions, particularly for wind.15

Conclusion

This analysis of the difficulties confronting the U.S., as well as its achievements, as it strives to promote the commercialization of solar energy, permits us to derive some important generalizations about the role of public policy in technological innovation. These can be divided into the two major dimensions identified above—the nature of the technology and the structure and functioning of the political system that shapes the policies that are adopted.

It is clear that different technologies pose different challenges along the innovation chain because of their different risk profiles, thus creating difficult challenges concerning the type and level of government support that is most effective. Any effort by the government to promote the innovation process must be based on a coherent long term strategy. To be successful, such a strategy must be based on economic rationality and consider the risk-bearing tendencies of private sector actors as well as the positive externalities that are involved with innovation activity. Moreover, given the nature of the innovation process and its various stages, different specific policy prescriptions are likely to be required for each stage and, probably, for different industrial sectors as well.

The ability to develop and implement long term, rational policies, however, is obviously not a universal attribute. Policies are the output of a political system. Developing and implementing such a technology policy approach requires a particular kind of decision making
process if it is not to be frustrated by the political and ideological orientations of political parties and decision makers as well as those of various private actors.

An important variable in this regard is the issue of the structural distribution of power, whether the state is “federalist” or “centralist.” Superficially it can be argued that the latter type is more likely to develop a more effective science and technology policy but this is not necessarily the case for there are many examples of such states, e.g., France, that are generally considered as lagging in this area. As to the former, states in the U.S. have considerable power and can be valuable crucibles of innovation though political considerations at this level can also lead to distorted policies.

Thus, the power of the vested interests within a political system and their ability to shape policy to further their own ends emerges as a critical variable. If they do not share a commitment to long term scientific and technological innovation or if they are so ideologically divided in a manner that prevents compromise, then that state is unlikely to prosper in today’s international environment where heated competition not only in solar energy but in so many other technological sectors is the norm.

Notes
1 Detailed discussions of the technological issues presented in this paper are to be found in the Home Page, posted on the website. The specific items are listed there as #1, #2, etc. For a technical discussion of solar energy, see #1.
2 This has important implications for the developing world. See Home Page, #2.
3 For more information on energy carriers, see Home Page #3.
4 On the PV effect see #4.
8 On the history and achievements of the DOE see the Home Page #5.
9 The details of the Solyndra affair are to be found in the Home Page, #6.
10 www.gop.com/2012-republican-platform_reforming/.
11 www.gop.com/2012-republican-platform_reforming/.
13 For a detailed discussion of this project, see Home Page #7.
14 These estimates are to be found on p. xx of the SunShot Vision Study (2012), a detailed analysis of the issues and problems that have to be dealt with to attain the Vision’s goals. See Home Page, #8.
15 See Home Page #9 for a discussion of their significance.

References


