China Environment Forum

Woodrow Wilson International Center for Scholars

This brief is part of a series under the China Environment Forum's Cooperative Competitors: Building New Energy and Water Networks Initiative, made possible by support from the Blue Moon Fund, Rockefeller Brothers Fund, U.S. Agency for International Development, and Vermont Law School

Solar Technology and Markets: Illuminating the Prospects for China and the U.S.

By Alan Campana

A series of fields in Inner Mongolia are being targeted for development into one of the largest farms of its kind; the kind that silently and immaculately produce 2 GW of electricity. When completed, the U.S. company First Solar's photovoltaic (PV) solar farm will be a landmark project, one that is indicative of the Chinese government's growing interest in the solar energy sector in its push to expand the country's green technology market while reducing the country's greenhouse gas emissions.[1]

Averaged out over a year across the globe, each square meter of earth receives about 4.2 kilowatt hours of solar energy per day, and the major energy consumers in the world—China, Europe and the United States—are taking the lead in harnessing this free energy. U.S. researchers have developed new technologies to convert and store solar energy and are pushing the efficiencies of solar photovoltaic panels to new heights, but the lack of price on carbon, lack of feed-in tariffs, and a federal renewable energy portfolio standard slows commercialization and market creation in the United States. Following more the European model, Chinese policymakers have created policy incentives and mandates to promote solar energy technology. These policies aim both to lower electricity production costs and to create a market in which firms can achieve economies of scale. Solar water heaters have long been in widespread use in the Chinese countryside and more recently rooftop solar panels in cities are starting to be installed.

CHINA'S RENEWABLE DRIVE

The driving policies for expansion of solar power have been the 2005 *Renewable Energy Law* and the 11th Five-Year Plan, both of which mandated 15 percent of the country's electricity be supplied by renewables by 2010. These policy and investment targets were echoed and extended in 2007 by the *National Development and Reform Commission's Medium and Long-Term Development Plan for Renewable Energy* that set what was initially seen as an ambitious goal of reaching 1.8 GW of installed solar by 2020.[1] The speed of PV installation has been so fast that this solar goal was recently trumped, and China now plans to have 10 to 20 GW of solar power installed by 2020.[2] These solar and broader renewable investment priorities and targets have sent a clear signal to investors and consumers that renewables will be an expanding part of the country's energy production mix for the long term. These policies, combined with various government subsidies, have given strong incentives to industry, which has catalyzed China to leap ahead to become the largest producer of PV cells in the world.

The Chinese government's Golden Sun subsidy program launched in mid-2009 will fund 50 to 70 percent of construction and connection costs of solar plants between 2009 and 2011, with a goal of 500 MW of newly installed solar power.[3] However this rapid solar infrastructure development has had mixed international reactions with cheers from environmentalists and jeers from foreign competition. For example, on September 9, 2010, United Steelworkers, the largest industrial labor union in North America, filed a trade case under the Section 301 of the U.S. Trade Act of 1974 alleging that the Chinese government has violated WTO free-trade rules in subsidizing solar panels and wind turbines for export. The union argues that such subsidies give unfair advantages to China's domestic producers of clean energy equipment.[4] .

The speed with which solar energy will take a significant place in China's future energy infrastructures is, however, questionable. Globally, currently installed solar capacity is dwarfed by other forms of renewable energy, making it one of the least field-tested of the green alternatives. Solar PV technology is also in the midst of a period of flux, with many young and still developing technologies in competition against each other. Moreover, alternative energy technologies in general are meeting with grid integration and transmission obstacles and policy-related problems. Without a clear path of development and strong incentives, the solar industry in China and elsewhere could founder, making only slow, halting progress towards its full potential.

INTENSE INNOVATION

Currently, commercial solar PV technology can be roughly divided into two categories, crystalline silicon and thin film. Crystalline silicon PVs use thin silicon wafers to capture sunlight[5] and this technology is currently the most efficient, converting nearly 20 percent of sunlight into electricity. However, the high cost of silicon wafers and energy-intensive production processes make the material of crystalline PV panels an issue of expense.[6] Globally, approximately 85 percent of solar energy is generated by single-crystalline or poly-crystalline silicon solar cells, in great part because of its high efficiency and longer history on the market.[7]

Thin film technologies involve a base (called a substrate) covered with a thin layer of a conductive material and are widely judged to hold the most potential for innovation in solar power production products in the near term. Thin film PVs use little or no silicon,[8] which allows for greater resource efficiency and automation in production. Moreover, the wider range of substrates that can be used have made thin film PVs a more flexible technology[9] and has spurred the creation of fairly innovative products such as solar power-producing roofing tiles. Most thin film technologies have lower efficiency than crystalline silicon panels and while some thin film PV cells have efficiencies of 15 to 20 percent in the laboratory, due to high production costs most companies can only afford to keep the efficiency of mass produced panels at around 10 percent.[10]

One of the key steps of thin film PV production is the method by which the conductive material is applied to its substrate. Reducing the energy intensity of this process and creating a more effective thin film coating are key to improving solar cells' cost and efficiency. As one of the main areas of innovation, competing companies often have their own distinct proprietary production process and design.

The variations in technology have created a solar PV industry that is highly competitive, and as a result it is dynamic and rapidly evolving. Such competition is pushing solar energy technology toward viability in a competitive market, and PV cell efficiencies are constantly improving as companies develop their technologies. In China it currently costs around 30 to 60 cents to produce a kilowatt hour of solar power,[11] much higher than average utility costs in the United States (8.9 cents).[12] Yet the U.S. Department of Energy predicts that many solar technologies will reach grid parity (calculated to be 10 cents per kilowatt hour) by 2015 or sooner.[13]

While the intense competition has led to a wide range of different PV technologies, none has a secure position as a standard in the market. Investment is being channeled into many different competing technologies; for example there are three different thin film technologies—amorphous silicon, cadmium telluride, and CIGS—and several different technologies either in use or in development as substrates. The resulting volatility of the PV technology market can discourage investment in the industry, since it is unclear whether any of these thin film technologies will become a viable industry standard. One encouraging development came from the silicon supply bottleneck, which increased prices before China's investments, created an overcapacity, and spurred more research and investment in thin film technologies.[14]

Thin Film Contenders

Three substances are currently being used in thin film PV technology and all are technologies that are being built or considered for the China market**.** Below is an analysis of the advantages and drawbacks of these materials and some information on their relevance to the Chinese market.

Amorphous Silicon

Crystalline silicon is the original solar PV panel, which uses silicon wafers to capture and convert sunlight. However, the silicon production process is energy intensive and waste products require processing, making silicon an expensive input. Although its sunlight conversion is comparatively efficient, the high cost both in terms of money and energy are a challenge in this technology.

Amorphous silicon is a newer technology that has three advantages over crystalline silicon. First, it is a thin film technology, so silicon use is drastically reduced. Secondly, amorphous silicon application has relatively low energy, low cost application processes. Third, amorphous silicon is an efficient absorber of photons both in the lab and in outdoor demonstrations. These characteristics have made amorphous silicon panels cheaper than crystalline silicon to produce and functional enough to be commercially competitive.

However, problems remain. While amorphous silicon panels use less silicon, silicon remains an expensive material. A drop in the price of silicon in 2009 has been partially due to production overcapacity in China. It is estimated that China can currently produce 20,000 tons of silicon per year, and projects presently underway will increase that capacity to 80,000.[15] However, total output in 2008 was only 4,000 tons, and the global economic downturn has further reduced demand for solar PV.[16]

This overcapacity from Chinese companies presents two problems for the technology's development in China. For one this overcapacity is hurting the development of the market, cutting into producers' profits. For another, silicon production is an energy-intensive process, and the Chinese government is trying to rein in energy intensive industries to lower pollution and ensure energy security. The Chinese government is planning to take steps, including regulating financing and withholding approval for new crystalline silicon projects.[17]

In addition to overcapacity, processing the toxic waste from silicon production is costly and energy intensive, and there are reports that some new silicon producers in China are avoiding processing costs through storage or illegal dumping, which artificially lowers the price of production. Specifically, with waste processing, production of 1 ton of silicon costs about $84,000. However, by avoiding waste processing costs, Chinese firms can produce silicon at $21,000 to $56,000 per ton.[18]

Cadmium Telluride

Cadmium Telluride (CdTe) is currently the cheapest technology on the thin film PV market and is the key to First Solar's success. It is a thin film technology with a low-

cost production process and although its sunlight conversion efficiency is low compared to that of wafer technology, compared to other thin film technologies, First Solar's panels demonstrate a much smaller decrease in efficiency in low light conditions. One drawback of CdTe technology is that cadmium is toxic. CdTe panels have a life of 20 to 30 years,[19] and the extent to which cadmium may seep into the environment from CdTe panels is uncertain.[20] Disposal is therefore an issue; although an eight-foot solar panel contains less cadmium than a size-C NiCd flashlight battery. [21] The best approach is for the panels to be processed at the end of their life cycle to avoid environmental damage from cadmium seepage. First Solar, in cooperation with Brookhaven National Laboratory, has developed a process to recycle the cadmium and tellurium from CdTe panels.

CIGS (copper inidium, gallium, diselenide)

CIGS is positioned to become another highly competitive PV technology. In development for the past decade, CIGS is now in production at several companies, such as IBM, Nanosolar, and the Chinese company New Energy Solutions. [22] It is also non-toxic and relatively cheap to produce compared to other PV films currently on the market. In studies carried out by the National Renewable Energy Laboratory, the CIGS thin-film solar cell reached 19.9 percent efficiency, setting a new world record for this type of cell.[23] The Chinese manufacturer called New Energy Solutions (based in Qingdao, Shandong Province) very recently started its own CIGS production, at a conversion efficiency of 9.5 percent. While still a nascent technology, it holds great promise in the near future.

NEED FOR STRONG GRID

In addition to panel technology problems, solar energy faces yet another hurdle in the realm of power transmission. Solar power is generated at a variable rate; panel position, time of day, weather, and seasons all affect the amount of sunlight that can be absorbed. Due to the lack of policy incentives and pricing, the current electrical grid infrastructure in many countries does not handle the ebbs and flows in solar power production. China is in the process of constructing massive high voltage electricity lines (aka "strong grid"), but the lack of an environmental dispatch system (the United States doesn't have one either), means power generators still favor tapping coal-fired power for cheaper electricity.

Furthermore, the richest solar resources tend to be far from load centers, as is the case in China. Both the United States and China face the challenge that current copper wire transmission is highly inefficient over long distances and do not have the capacity to transmit the huge amounts of electricity—a problem particularly acute in China where energy consumption rates are growing steadily as urbanization and growing consumerism in cities increases.[24] The Chinese government is thus moving quickly to invest in efficient high voltage power transmission lines, which will be key in creating a more technologically advanced power grid that can incorporate energy effectively from solar and other renewable sources. For more information on trends in power transmission in China, see the China Environment Forum's brief exploring smart grid as an area for U.S.-China cooperation.

U.S. AND CHINA IN THE SOLAR MARKET

China is quickly developing a large PV industry that includes all aspects of the production process from polysilicon feedstock, ingots and wafers to module production. There are over 50 solar cell producers and over 300 solar module producers in China, and the average efficiency of the cells produced is 15 to 16 percent. In 2008, panel production was estimated between 2.3 and 2.9 GW and for 2009 panel production was at 3.8 GW[25] which was notably less than the predicted 8.9 GW. [26] In addition to building its industrial production capacity, China is trying to increase its domestic market for solar energy. These efforts have included government subsidies of solar electricity to bring the cost of solar to parity with conventional electricity production, as well as programs to encourage infrastructure building. The Golden Sun program, for example, provides a government subsidy of 50 percent for investment in PV power generation systems.[27]

Solar energy is just one element of a larger renewable energy drive in China, which, at the moment, appears to be gaining momentum. Although China currently stands as the largest greenhouse gas emitter, the government's move toward clean energy has had ambitious goals and tangible results; the China's National Development and Reform Commission

has set a national renewable energy production goal of 15 percent by 2020, and expects to exceed it.[28] China's National Bureau of Statistics announced that in 2008, nine percent of the country's energy came from carbon-free sources such as wind, solar, hydro, and nuclear power.[29]

A March 2010 report by the Pew Charitable Trusts ranked China as the number one investor in clean technology surpassing the United States nearly twofold in 2009—China's public and private investment reached 34.6 billion to the U.S. 18.6 billion. China's leap to number one status stems from three significant R&D investment programs and $47 billion devoted to clean technology in the 2009 stimulus package.[30] An UNEP and Bloomberg New Energy Finance report analyzing China's 2009 stimulus package noted that the government's financial investment in clean energy grew by 53 percent from 2008 to 2009.[31] China's upcoming 12^{th} Five-Year Plan is likely to include more clean technology investments to meet the continued aggressive energy intensity decreases and targets to significantly lower in CO_2 intensity as a percentage of GDP. Solar power will inevitably play a key role as the Chinese government also moves to meet the domestically binding targets it set in December 2009 at the global climate talks in Copenhagen to reduce CO_2 emissions per unit of GDP by 40 to 45 percent by 2020 (compared to 2005 levels).

While China is the leading producer and exporter of solar energy technology, the United States is the third largest solar market with 342 MW of new solar installations. Panel production reached 414 MW in 2008, and, strikingly, 28 percent of the U.S. market share is in thin film technologies, significantly higher than the global average of six percent.[32]

Policy incentives to promote solar energy in the United States have been largely lacking at the federal level—the most notable policy gap is a lack of renewable energy standards or feed-in tariffs, both of which exist in China. A special two-year 30 percent tax credit was implemented in the United States in 2005 to promote business and residential solar use, and in 2008 this program was extended to 2016. In addition, $51.5 million of the American Recovery and Reinvestment Act has been going towards PV technology development, and $40.5 million has been committed to technology deployment. In October 2010 the Obama Administration announced that solar panels would be installed on top of the White House, which is a potentially powerful sign that the Obama Administration is committed to promoting solar power. While a the passage of a climate bill in the U.S. Congress seems unlikely in the near future, it is notable that in September 2010, a bipartisan group of senators unveiled a bill to create a federal renewable energy standard.

Policy in some states, California in particular, has been more aggressive in giving incentives to promote manufacturing and demand by the electric utilities and consumers encouraging this industry. Of all 50 states, only Alabama has no financial incentives for renewable energy use, and at least 39 state programs include incentives for PV. Incentives include various tax exemptions, loans, grants, and rebates. In the case of California for example, in 2006, the California Public Utilities Commission adopted the California Solar Initiative, with a goal of reaching 3 GW installed solar capacity by 2017. The Initiative provides performance based financial incentives for customer-sited installations (including at residential, commercial, NGO, and government sites, as well as larger systems.[33] Notably, China's policies have focused much more on encouraging production of PV panel production for export rather than creating incentives for electric utilities or consumers to use solar energy.

Solar Policy Fusion

A number of mutual benefits could be reaped through U.S.-China cooperation on development of the PV industry. The positive effect on the environment of moving to a cleaner energy source would be significant; clean energy production would directly address the climate change issue. Solar energy is also one approach to greater energy security, a growing concern of both the United States and China. The November 2009 Obama-Hu energy agreements included the priority of creating a joint renewable energy roadmap, which can notably build on over thirty years of official cooperation and the joint projects and research U.S. and Chinese laboratories have undertaken.

Both countries would also share domestic benefits. Expansion of the solar industry could lead to job creation in both countries. Although there is a concern in the U.S. that manufacturing jobs will go to China, there are companies in

the United States that can compete with Chinese firms in terms of price, as in the case of First Solar and its successful bid to provide China with a PV power station. Moreover, many firms in both the United States and China are quick to point out that manufacturing jobs are a only about one-third of the jobs that the solar industry would create; the remaining 60 to 70 percent are created in the country that uses the panels.[34] Such jobs range from suppliers and distributors to site surveyors and assessors, project developers, engineers, and system integrators and assemblers.[35] According to a study by the European Photovoltaic Industry Association, for every megawatt of solar power, approximately 40 local jobs are created: 33 in the installation of the facility, 3-4 wholesalers or indirect suppliers, and 1-2 research-oriented positions.[36]

One approach to cooperation would be best practice sharing. The United States and China have approached solar industry development differently, and lessons learned from the different approaches could be beneficial. For example, the California Public Utilities Commission has developed a pricing system for renewable electricity that reflects the true value of electricity generated at different times of day so that electricity generated during peak hours is priced higher relative to that generated during low demand periods.[37] This has helped renewables like solar become viable on the market as the price of renewable energy is competitive at peak period prices.

Similarly, China's recent policies may provide useful lessons for U.S. policymakers. In 2009, the Chinese government implemented a feed-in tariff, based on the European model to promote renewable energy usage. Moreover, the central government also has amended the *Renewable Energy Law* to require grid companies to connect with and purchase electricity from renewable sources while simultaneously providing a fund to mitigate the cost. Such a policy may make investment in renewable utilities more attractive and secure.[38]

Cooperation on policy coordination could bring other benefits to both sides. Some examples of policy coordination that the private sector would like to see include coordination on grid standards that could improve connectivity allowing companies to work with a single universal standard. Product standards on quality and environmental impact would also be beneficial and would provided quality assurance to consumers and protecting the image of the solar industry in general.[39]

KEEPING THE BILATERAL MOMENTUM ON SOLAR

The momentum of U.S.-China bilateral cooperation on solar technology, among other types of renewable energy, is high and growing. Moreover, the prospect of solar energy being a key force in the global effort of climate change mitigation and the enormous market potential in both countries have led to a series of top-level dialogues and agreements that could become a strong foundation for cooperation between U.S. and Chinese businesses, research institutions as well as state/provincial and municipal governments. One of the top-level initiatives set up by the clean energy agreement jointly signed by President Obama and Chinese president Hu Jintao in late 2009 is the U.S. – China Renewable Energy Forum, the goal of which is to spark ideas and practices promoting renewable energy and to explore opportunities for U.S.-China collaboration to advance clean energy. During the two-day forum, solar emerged as one of the four priorities for U.S.-China clean energy cooperation; specifically, the issue of power grid integration and the concentration of advanced solar technologies were emphasized in particular. U.S. and Chinese authorities working on the renewable energy forum met for productive talks in May 2010. This now ongoing highly productive dialogue has created a framework for business-to-business renewable energy collaboration between the two countries. As an example of U.S-China business cooperation, the Chinese power utility ENN has recently purchased a U.S. solar production line from Applied Materials in hopes that advanced technology will give ENN a technological edge in Chinese and international markets. ENN is also in negotiations with Duke Energy and other parties on a building utility-scale solar project in the United States.

However, the high momentum on the bilateral level cannot be maintained without vigorous and timely actions in the domestic arena. China has been showing its commitment to solar and other renewables, not only in creating enabling policies to stimulate investment, but also through massive state funding of ultra-high voltage transmission lines that will enable huge wind and solar farms out west to transfer

power to the cities.[40] In the United States, the Obama Administration has been pushing for the creation of feed-in tariffs and a renewable portfolio standard to stimulate solar and other renewable development in the country so as to become a leader. It is nevertheless worth mentioning that the differences in the policymaking mechanisms between the two countries are in this case very likely to slow down the implementation of policies with major impacts on industry and the job market particularly given the fragile economy in the United States; this may have impact on the bilateral agenda at some later stage.

Because the solar power technologies are rapidly evolving, they are beginning to overcome market obstacles and become increasingly competitive. The technology is one part of the solution to environmental and energy security problems about which both the United States and China have concerns. Development of the industry is not a zero-sum game; both sides can benefit economically through cooperative policy to help the PV industry reach its potential in the market. And the time to act is now.

The author would like to thank Polly Shaw, Maja Wessels, and Derek Vollmer for their input, as well as many on the CEF team who helped with this paper— Kexin Liu, Peter Marsters, Natalie Matthews, and Jennifer Turner.

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