Getting Out of the Shade: Solar Energy as a National Security Strategy

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In recent years, China has emerged as the world's largest manufacturer of solar photovoltaic (PV) panels. Driven largely by strong demand in Europe, almost all of the solar panels manufactured in China have been exported to overseas markets. However, the current global financial crisis, coupled with recently dampened financial incentives for solar power in some parts of Europe, has significantly contracted overseas markets. The solar manufacturing industry in China is, as a result, under intense pressure to fend off what appears to be a bursting "bubble." By promoting China's domestic solar market, however, the Chinese government is presented with a unique opportunity to sustain the domestic solar industry, create more jobs, and enhance energy and environmental security. To be spurred into action, however, China's planners must appreciate the true value proposition of solar, understand the present bottlenecks limiting solar deployment, and respond with appropriate policy actions to overcome these hurdles so as to create a vibrant domestic solar market.

Few issues keep China's national planners awake more than energy and environmental security. China obtained 80 percent of its electricity generation from coal in 2007.[1] As the strains of a coal-based energy structure are being felt, China faces an enormous economic, environmental and social balancing act. China's planners feel

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the necessity to take advantage of China's plentiful coal resources to ensure a supply of affordable and reliable power for its citizens, so as to maintain economic and social order. However, the geographic mismatch between China's coal resources concentrated in the central and western regions, and where power is most used along the eastern coast creates long, unwieldy supply chains that are susceptible to disruptions, such as natural disasters. Logistical challenges posed by finite rail capacity mean that China relies heavily on coal imports to supply coal to certain parts of the country, particularly the southeast. Although China boasts a third of the world's coal reserves, it became a net importer of coal for the first time in 2007.[2]

The use of coal is plagued with unaccounted social costs and fuel price volatility. The health and environmental impacts of coal use are significant. In 2007 alone, some 3,786 coal miners died in mining accidents.[3] The extraction, processing, transportation and combustion of coal produces significant water, air and solid residue pollution with all its public health implications. With China soon, if not already, surpassing the United States as the largest emitter of greenhouse gases, and with the Kyoto climate treaty up for renegotiation, there is strong international pressure on China to actively reduce its emissions, to which coal-fired power is a major contributor. The proposition of coal as a cheap and reliable source of power is quickly losing cache, undermined by the combined economic risks from rising social costs and unpredictable coal prices, which have nearly halved since peaking about ¥1,000 in mid-2008.[4]

The need to diversify and clean up China's power sources is not lost on the central government. It has undertaken a variety of measures, from the prioritization of energy efficiency to the promotion of clean alternative energy development through the passage of the Renewable Energy Law in 2006. Solar energy represents a promising energy alternative that directly addresses many of the shortcomings of coal-fired power. China's solar resources are abundant, averaging 4 kWh/m^2 of radiation in most areas and representing a similar resource level to that of the United States, and much more than that of Japan and Europe.[5] However, while there has been enormous global investment interest in developing solar technologies over the past three years, limited government support and the recent sharp financial downturn has created uncertainties in the prospects for the mass deployment of solar energy systems in China. Yet, there may be a silver lining.

The Solar Opportunity

Amidst the global financial downturn, three trends are causing solar PV module prices to decline steeply, leaving an opening for aggressive government action to promote the deployment of solar domestically.

First, the price of polysilicon feedstock, which is the key raw material in the predominant type of solar panels in the PV market, has declined significantly from a high of over $400 per kilogram in mid-2008 to about $100 per kilogram by the end of the same year.[6] The increased supply from newly completed polysilicon production plants planned for in the solar boom years of 2006 and 2007, together with the softening of overseas demand for solar panels and the expanding market share of non-silicon-based PV material, are expected to keep polysilicon prices depressed in 2009.[7] Second, there has been a sharp decrease in solar module demand in Western markets due to the global recession and a reduction in incentives for solar energy in key markets such as Germany and, especially, Spain.[8] Worldwide revenue from the shipment of solar PV panels is projected to decrease by 20 percent in 2009 compared to the year before.[9] Third, until the recent crimping of overseas markets, solar manufacturers were on a trajectory to expand production capacity and improve economies of scale.[10] With the combined effect of reduced input costs, weakened demand and increased supply, solar module manufacturers are already reportedly slashing module prices by 30 to 40 percent.[11] Meanwhile, facing a growing oversupply, many smaller Chinese solar manufacturers are struggling to remain in business.[12]

In these uncertain times, government support is vital for the development and deployment of solar power. Currently, the domestic solar PV market is essentially non-existent. In 2007, more than 95 percent of the solar modules manufactured in China were exported.[13] At the end of the same year, a mere 100 megawatts (MW) of solar power was installed (of which only 5 MW were of the distributed, roof-top sort), compared to about 6,000 MW of wind and 513,000 MW of coal.[14] The root of government inaction in China and internationally is that when viewed in narrow economic terms, solar energy seems much more expensive than coal. In the face of China's enormous environmental, energy and climate change challenges, solar energy's advantage as a clean and abundant energy source is widely recognized, but far less discussed are the efficiencies and other benefits over centralized coal power generation that solar can bring if used as a distributed energy resource. None of the foregoing "positive externalities" are currently valued into the price of solar.

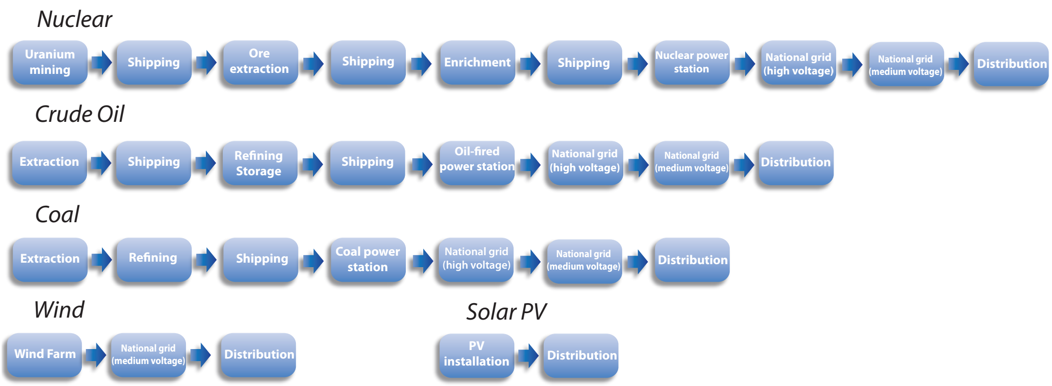
Given the entrenched nature of China's fossil fuel infrastructure, it is unrealistic for solar energy to significantly displace coal as the dominant electricity fuel source in the near or medium term, but the government can take advantage of the current unique financial situation to adopt measures that will significantly accelerate the utilization of domestic solar resources. There is a compelling national security case for developing China's domestic solar market, but reaching this conclusion requires a better understanding of the true value of solar energy, economic or otherwise, of what makes it competitive or even superior to its fossil fuel counterparts.

Redefining National Security

Framing the case for solar in terms of national security will create a stronger impetus for government action in promoting solar energy. In making this case, conventional notions of national security need to be broadened to encompass energy security, economic security, social security and environmental security.

Although there are various sorts of commercially available solar technologies, this article will focus on distributed solar PV systems that are typically associated with roof-top installations, rather than large utility scale solar farms because of the former's unique supply chain advantages. The abundant nature of solar resources means that distributed solar PV systems have a significantly shorter supply chain than fossil energy systems. Short supply chains are advantageous because they translate to reduced transportation and infrastructure build outs, which directly improve environmental and economic performance, and maximize benefits to the local economy.[15] With distributed solar, the supply chain is virtually nonexistent; solar power is converted by the solar panel into electricity that is fed through just a few meters of cable before being used.[16]

Comparison of Supply Chains for Electricity Generation



Source: Hermann Scheer, *The Solar Economy: Renewable Energy for a Sustainable Global Future* (2002).

A distributed energy system, such as a network of rooftop PV, is a more resilient energy system than a centralized one because it consists of numerous, relatively small modules, each able to function independently of each other and each with a low individual cost of failure – meaning the disruption of one or few nodes within the network of the distributed renewable energy system will not bring down the entire system.[17] Centralized energy systems, such as coal-fired power plants, are the opposite, consisting of one or few large centralized units that are more vulnerable to high-cost failure.[18] As the ice storms of early 2008 in southern China demonstrated, centralized coal-fired plants are highly vulnerable to bottlenecks along their long supply chains; the high-cost failure manifested itself in 17 provinces, municipalities or autonomous regions that experienced power failures or reduced power supply as a result.[19] Distributed solar energy systems, on the other hand, are placed very close to the end-use, thereby dramatically reducing the supply chain and potential points of vulnerability.[20] Where solar systems are grid-connected and feed in excess energy generation to the grid, solar systems can also enhance the resilience of the grid.

Another aspect of security is reliability. While renewable energy resources have been dismissed for intermittency, the causes of variations in solar resources (e.g. diurnal cycles, cloudiness, etc.) are well understood and fairly predictable.[21] Centralized large-scale power, on the other hand, is intermittent for reasons that are far less predictable. Occurrences such as extreme weather conditions or terrorist strikes are more likely to disrupt entire energy systems based on centralized production than distributed production, as it is less likely all the nodes of a distributed network will be impacted.[22] Moreover, technological advances in energy storage, sun tracking and shade mitigation are extending the use of solar power throughout the day. The result is that the lifecycle costs for solar power are more certain than for centralized fossil fuel plants, whose fuel costs remain subject to volatile market forces.

The social advantages of solar should not be underestimated.

In the wake of the global financial downturn, developing new energy sources domestically offers compelling economic security propositions in diversifying economies that have been heavily dependent on low value-added exports. The rapid emergence of China as the world's leading manufacturer of solar PV panels has made meaningful contributions to China's economy, providing 10,000 jobs as of 2007 that are expected to increase tenfold to 100,000 by 2020.[23] However, since over 95 percent of domestically produced solar panels are exported, the multiplier effects of building a robust domestic solar PV market, which would create a hitherto nonexistent ecosystem of parts manufacturing and installation expertise, have not been realized. If China wants to head off a steep decline in economic growth in these turbulent times, developing a domestic solar market provides some interesting possibilities.

Finally, the social and environmental advantages of solar should not be underestimated, especially for a government whose legitimacy rests heavily on maintaining the social fabric. At the end of 2006, some 11 million rural dwellers lacked access to any electricity.[24] Off-grid solar panels represent the most practical and economic choice for the reduction of the energy poverty gap in many remote rural areas that are currently off-grid and the focus of rural electrification, one of the government's most important social programs.[25] Policymakers must also recognize the public health costs that the entire supply chain of coal power production imposes, including the health and lives threatened in coal mining, as well as the harmful emissions of sulfur dioxide and nitrous oxide emissions. A recent study concluded that the negative environmental, public health and other social costs of China's coal industry (excluding climate change impacts) add up to ¥1.7 trillion per year.[26]

Reconsidering Solar Economics

Even with a 40 percent drop in solar module prices, and assuming installation costs remain roughly unchanged, installed solar PV power would cost, on a per kWh basis, some eight times as much as coal-fired electricity. Framed in such narrow economic terms, this gap is a mental barrier for policymakers to create robust financial incentives for the adoption of solar power. It has been suggested that the central government should wait for the expected demand from the United States, which has recently passed strong financial incentives to promote solar adoption, to further scale up solar module production in China and further drive down module prices.[27] Indeed, it seems that China's current policy for solar, as outlined in the 11th Five-Year Plan for Renewable Energy, adopts this wait-and-see approach in the form of cautiously modest targets for installed solar capacity by 2010. The 2010 target of 300 MW of total installed solar capacity, which includes non-distributed and non-PV (i.e. STEG plants) solar, pales in comparison to the 874 MW of PV installed in the United States by the end of 2007,[28] or the 12,300 MW of wind installed in China by the end of 2008. But such a cautious approach, which reflects a psychological hang up on the price disparity between solar and fossil fuels, misses entirely the aforementioned national security proposition of solar.

Installed Solar Capacity at 2007 Compared to 2010 Targets under the 11th Five-Year Plan for Renewable Energy

Application	2007 Installed Capacity (MW)	2010 Target (MW)	Main Development Regions
Applications in remote areas	55	150	Tibet, Qinghai, Gansu, Xinjiang, Yunnan, Sichuan
Buildings	4.8	50	Beijing, Shanghai, Shandong, Jiangsu, Guangdong
Grid-connected PV power stations	0.2	50	Lhasa of Tibet, Dunhuang of Gansu, Ordos of Inner Mongolia
Solar Thermal Electricity Generation (STEG) plants	0	50	Inner Mongolia
Other commercial applications, e.g. street lamps	40	N/A	N/A
Total	100	300	N/A

Source: Julia Wu, et al., "China's 11th Five-Year Plan: Wind and Utility-Scale PV Targets are Up, but RPS is Gone," New Energy Finance, April 11, 2008.

More crucially, the true cost of deferring the replacement of coal power with clean solar power is often missed by policymakers, and certainly by the private sector. Such cost cannot be measured solely in economic terms, but must also include the increased difficulty in mitigating greenhouse gas emissions. Experts are in general agreement that a 60 to 80 percent reduction in greenhouse gas emissions is needed by 2050 compared to 1990 levels in order to stabilize climate change.[29] Because coal power infrastructure has a lifecycle of 40 to 50 years, we are really talking about energy investment decisions that have to be made today. Each megawatt of solar power deferred today is an additional megawatt of coal power that will spew greenhouse gases for the next 40 or 50 years.

Even if the aforementioned benefits seem too intangible to value, there are three additional economic considerations. First, solar PV power, while not generally cost competitive with "base load" grid-based electricity, is in many regions cost competitive with "peak load" power, which is turned on when power demand reaches the highest point during the day.[30] Peak load power is the most expensive type of power for utilities to produce and usually occurs at, or overlaps partially with, the hottest time of the day when the sun shines brightest and power consumption is at its highest. Solar power is the ideal strategy for "peak shaving."

Second, decentralized energy systems eliminate the need for expensive, inefficient and resource-intensive transmission and disitribution (T&D) infrastructure. The State Grid of China, which is already under financial pressure after an 80 percent drop in profits in 2008,[31] plans to spend a whopping ¥1.16 trillion over the next two years on grid construction.[32] Not only are network losses experienced in T&D estimated to range between 8 and 9 percent,[33] but the construction of every 100 km of power lines of a 500-kV grid project reportedly requires 5,000 tons of steel, 2,000 tons of aluminum and 7,000 cubic meters of cement.[34] While the need for expensive T&D capital outlays cannot be eliminated in each and every case, stand-alone distributed PV systems are a highly economical choice in remote rural areas that lack grid access. The recently announced utility-scale solar farms in Qinghai's Qaidam Basin (1 gigawatt (GW) installed capacity) and Yunnan's Kunming city (166 MW) are a step in the right direction towards a low carbon economy, but the reliance of these projects on T&D infrastructure means that they are clearly not the final destination that distributed energy solutions such as PV represent.

Third, the simultaneous use of solar panels for applications other than power generation can improve its economics. For instance, the installation of rooftop solar panels can reduce a building's air conditioning load by shading the roof. There are also so-called building-integrated photovoltaic (BIPV) applications, where the PV panels are not installed on top of the facade of a building, but *as* the facade of the building, eliminating the need for conventional building materials.[35] Furthermore, when such BIPV installation is wrapped into the mortgage of a new building, additional financing becomes unnecessary and the PV system can be financed using some of the cheapest available forms of long-term finance. BIPV's improved economics represents a major opportunity for China, where McKinsey projects that some 40 billion square meters of floor space in five million buildings will be built by 2025.[36]

Finally, the modular nature of solar PV means that it can be installed in stages, panel by panel, or solar farm by solar farm, allowing electricity production to begin shortly after construction commences but before it is finished, thus greatly enhancing the economics of solar power. This is in contrast to large centralized power plants, which take years to build and cannot generate power until construction is completed. The opportunity cost associated with the lag time of planning to construction in large-scale fossil fuel plants is rarely taken into account in the economic analysis when comparing relative costs of different energy options. When coupled with decentralization, modularity also means that the generation capacity of solar systems is scalable and more likely to match demand, reducing instances of overcapacity and hence inefficiency that are now being experienced in China's coal power sector.[37]

While it is beyond the scope of this article to quantify to what extent the foregoing considerations reduce the cost of solar PV power over coal-fired power through an "apples-to-apples" comparison, one authorative study estimates that the the financial benefits of employing a distributed energy system can exceed those of a centralized system by as much as a factor of ten.[38] If accurate, this would offset the cost difference between solar and coal-fired power.

Recognizing Solar's Own Bottlenecks

There will certainly be challenges to deploying a scaled-up solar program. The true value economics of solar may be difficult to convey to the average end-user. While PV installations offer the advantage of upfront cost certainty due to zero fuel costs and minimal operating and maintenance costs, it is also true that the upfront costs are significant. Given the choice between heavily subsidized retail rates of electricity and making a hefty upfront investment in a solar installation that will only pay itself back in 20 years or more, it is easy to guess which option usually wins out.

Reorienting China's solar industry towards the domestic market will require broadened competencies across the solar value chain compared to one geared towards exports. Solar panels are just one of various components that make up an installed solar PV system. Non-panel components, also called "balance of system" (BOS) components, include devices such as batteries, controllers, inverters and monitoring devices. Due to the export focus of the Chinese solar industry, there has been far less emphasis on building production capacity on BOS components. For instance, it is reported that at current rates of solar PV use, most of the controllers and inverters needed for stand-alone and medium-scale grid-connected solar systems are domestically sourced, while a larger portion of controllers and inverters for larger-scale grid-connected solar systems are imported.[39] Should the domestic solar market be significantly expanded, current domestic BOS production capacity will not be sufficient.

Deploying distributed solar PV will also require a skilled workforce to market, sell, install and maintain PV installations. A warning shot has been sounded by China's wind power industry, where a boom in wind farm development domestically has led to a shortage of skilled labor to maintain the wind facilities.[40] Similarly, the installation of PV, especially of the distributed sort, is a relatively labor-intensive process which requires technical competence. All the financial incentives and appropriate technologies will be of little use if there is no one to physically deploy the solar systems. That said, there are measures that the government can take to address these concerns as it seeks to promote the domestic solar market.

Getting Out of the Shade

The time to jump-start China's domestic solar market is now. Given the financial malaise in the United States, it is by no means certain that US demand will pick up soon despite its recent enactment of financial incentives for solar. Rather than depending on foreign markets to drive down the production costs of solar, China can do it by itself. A coordinated scaled-up investment program in developing solar resources at this time is not only consistent with the public government statements that environmental protection and new energy technologies should be a focus of the recently announced ¥4 trillion economic stimulus package,[41] but would also take advantage of the current historically-low prices of solar PV panels. Such a program would involve a mixture of internalizing the externalities of fossil-based power, providing financial incentives to recognize the non financial benefits of clean, distributed solar power, and the development of technical capacity to create a domestic solar market.

One of the more direct ways for solar energy to move towards "grid parity" is to accelerate retail electricity price reform. The recent massive infusion of funds by the government into the "big five" power generation companies to stem their record losses in 2008 reflect the fact that retail power, which is fixed by the government, is priced below its cost of production.[42] The reforming of energy prices towards more market-based mechanisms has become a theme in recent energy policy documents,[43] and has already made its effect felt with the upward adjustment of retail electricity rates last July, and reports that further increases may be imminent.[44] The sooner prices are made to reflect even just their current costs of production (let alone negative externalities), the quicker solar power can compete with coal-fired power on a level playing field. As a longer term goal, the complex task of varying electricity rates throughout the day according to demand levels should be undertaken so as to more effectively harness the "peak shaving" value of solar power.

Rather than depending on foreign markets to drive down the costs of solar, China can do it by itself.

The government should also implement comprehensive feed-in tariffs, which would require grid companies to purchase solar power at preferential tariff rates and which have been proven in Germany and elsewhere in Europe to be the most effective policy instruments in promoting renewable energy utilization.[45] The premium that these tariff rates represent over the tariff of conventional fossil fuel electricity should be fixed, but also gradually decreased over a period of 10 or 20 years. These premiums should be paid by the grid company to the solar power producers and passed down and shared across all end-users, in accordance with the landmark Renewable Energy Law that was enacted in 2006 but has hitherto received selective implementation. Such a system also directly rewards production of solar power rather than merely installed capacity, which says nothing about how much electricity is actually generated.[46] A related mechanism, net-metering, should be implemented to allow smaller scale users to offset their electricity bills by feeding back any excess solar power not used back into the grid.

Another way to ramp up demand for solar is through government procurement. The initiation of mass deployments of solar panels in central and provincial government facilities and commercial facilities of large state-owned enterprises creates a strong market signal for the scaling up of PV deployment and subsequent lowering of costs. The government can also act as a lever for demand by accelerating its rural electrification program through the purchase and deployment of solar systems where they are feasible, and require its state-owned utility companies to take advantage of their relationships with end-users to roll out distributed solar programs.[47]

With respect to end-users, financial innovation can positively alter the cost perceptions of solar. Third-party financing arrangements – whereby a third-party financier purchases, installs and continues to own the solar panels, but sells the solar-generated electricity to the facility owner just like a utility – relieves the facility owner of prohibitive upfront costs of installing and owning the solar panels. Due to the nascent development of consumer credit, such third-party financing institutions should target commercial and industrial entities, rather than the residential sector, and perhaps with the support of provincial and municipal governments, which have energy efficiency and renewable energy goals to meet.

Meanwhile, policies should be made to develop the necessary capacity and technical expertise for all steps of the PV value chain, especially the manufacturing of peripheral components, and for downstream solar activities such as systems integration, installation and after-sales services, such as performance monitoring, system repairs and upgrades. Another area of attention is the upgrading of the electrical grid so that it can accept interconnections from distributed solar systems. This will require significant investments in education and infrastructure, but also lead to significant positive externalities such as job creation and spill-over benefits to other electrical engineering sectors.

A group of major Chinese PV manufacturers recently submitted an industry white paper to the government expressing optimism that solar power can achieve price parity with conventional fossil fuel power as early as 2012.[48] This will not happen, however, without the weight of more aggressive government policies, which China's planners should adopt in order to seize current opportunities and enhance national security. The national security proposition of solar energy is rooted in the unique economic and noneconomic benefits of its distributed nature and shorter supply chain. Clean, distributed solar power can enhance the resilience of China's power supply, produce clean power in urban and rural areas alike, and provide high-skilled jobs. Instead of shipping China-made solar modules to distant western markets, deploying them domestically would further enhance the benefits of shorter supply chains. The unique confluence of lower productions costs and decreased overseas demand means the cost of going solar is lower than ever and makes it an opportune time to make a policy push for domestic solar deployment.

Notes

1 Cambridge Energy Research Associates, *Feeding the Dragon,* 2008.

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3 "Chinese coal mine deaths down 20% in 2007," *Xinhua News*, January 12, 2008, http://www.chinadaily.com.cn/china/2008-01/12/content_6389679.htm.

4 The price of coal dropped from ¥1,000 per ton in mid-2008 to half that now. Si Tingting, "Coal Proce Drops Sharply at Qinhuandao," *China Daily*, at http://www.chinadaily.com.cn/bizchina/2009-02/18/content_7489094.htm

5 Li Junfeng, et al., *China Solar PV Report 2007*, p. 6.

6 Liang Zhongrong, "guangfu fadian jia chengben dafu xiajiang: 1 yuan/du guangfu fadian fang'an shangjiao kejibu" (光伏发电价成本大幅下降：1元/度光伏发电方案上交科技部), *21st Century Business Herald*, February 6, 2009, at http://www.21cbh.com/HTML/2009/2/6/HTML_J6PBFB1A0D14.html.

7 See, e.g., "PV Costs set to plunge for 2009/10," *Renewable Energy World*, December 23, 2008, http://www.renewableenergyworld.com/rea/news/story?id=54380&src=rss.

8 Ucilla Wang, "Solar Prices Set in Germany," Greentech Media, June 6, 2008, http://www.greentechmedia.com/articles/solar-prices-set-in-germany-980.html and Martin Roberts, "Spain Ratifies New Solar Subsidy Cap," *Reuters*, Sept. 26, 2008, http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE48P7JW20080926?sp=true.

9 Zhang Qi, "Sun is Setting on China's Solar Industry," *China Daily*, January 19, 2009, p. 5.

10 Ibid.

11 Personal communication with Julia Wu, solar analyst at New Energy Finance, Dec. 10, 2008. See also Josie Garthwaite, "Suntech CEO: Solar Panel Glut to Slash Prices by 30% in 2009," *Earth2Tech*, December 8, 2008, http://earth2tech.com/2008/12/08/suntech-ceo-solar-panel-glut-to-slash-prices-by-30-in-2009/.

12 See, Nuying Huang, "China PV module sector sees departure of 70% of makers," *Digitimes*, January 15, 2009, http://www.digitimes.com/news/a20090115PD210.html.

13 Zhao Yuwen, wo guo guang fu chan ye fa zhan gai kuang ji si kao (我国光伏产业发展概况及思考), 10th China Solar Conference and Exhibition in Changzhou, Jiangsu Province, September 19, 2008.

14 Cambridge Energy Research Associates, *Feeding the Dragon*.

15 Hermann Scheer, *The Solar Economy: Renewable Energy for a Sustainable Global Future* (2002), pp. 76-82.

16 While it is true that the manufacture of PV panels have their own supply chain with processes involving the purification and fabrication of silicon raw material; manufacture, assembly and installation of PV modules and peripheral components; a similar level of scrutiny of the lifecycle costs of building, operating and maintaining power plants. Associated transportation systems for fossil fuel power will make the supply chain comparison weigh even more heavily in favor of distributed PV. Ibid, pp. 74-75.

17 Amory B. Lovins and L. Hunter Lovins, *Brittle Power, Energy Strategy for National Security*

(1982, new ed., 2001), pp. 264-266.

18 Ibid.

19 "China suffers power shortage as winter storm brings chaos," *Xinhua News*, January 30, 2008, http://www.china.org.cn/english/China/241362.htm.

20 Lovins and Lovins, *Brittle Power*, pp. 264-266.

21 Lovins and Lovins, "The Fragility of Domestic Energy," *The Atlantic Monthly*, November 1983, pp. 118.

22 Ibid.

23 Li Junfeng, et al., China Solar PV Report 2007, p. 6. Li and the other authors estimate that a total of 47 to 49 jobs per MW of installed solar power capacity are created in the manufacturing, wholesaling, installation and research activities associated with the solar value chain.

24 Ibid.

25 National Renewable Energy Laboratory, "Renewable Energy in China: Township Electrification Program," April 2004, http://www.nrel.gov/docs/fy04osti/35788.pdf.

26 MaoYushi, Sheng Hong and Yang Fuqian, *The True Cost of Coal* (2008),http://act.greenpeace.org.cn/coal/report/TCOC-Final-EN.pdf.

27 Presentation by Thomas J. Toy, US-China Green Energy Conference, Beijing, November 17, 2008. As part of the United States' financial stimulus package passed in October 2008 (H.R. 1424, the Emergency Economic Stabilization Act of 2008), incentives for renewable energy were included, including an eight-year extension of the investment tax credits for solar and the raising of the cap on tax credits that owners can claim on the cost of installing their solar system.

28 US Department of Energy, Renewable Energy Databook, Sep 2008, available at http://www1.eere.energy.gov/maps_data/pdfs/eere_databook_091208.pdf.

29 See Nicholas Stern, The Economics of Climate Change (2006), p. 197. ("To stabilise concentrations of carbon dioxide in the long run, emissions will need to be cut by more than 80% from 2000 levels.")

30 Travis Bradford, *The Solar Revolution* (2006).

31 "China's State Grid profits down 80% in 2008," *Xinhua News*, January 18, 2009, http://news.xinhuanet.com/english/2009-01/18/content_10678968.htm.

32 "China to invest $169.9b in grid construction," *Xinhua News*, November 17, 2008, http://www.chinadaily.com.cn/bizchina/2008-11/17/content_7211671.htm.

33 See Wu Jian Dong, aobama nengyuan xinzheng po ke zhongguo jiang yinglai lishi tiaozhan (奥巴马能源新政破壳 中国将迎来历史挑战), Dong Fang ZHao Bao, January 21, 2009, http://www.wefweb.com/news/2009121/0846416834_1.shtml (in Chinese).

34 "China to invest $169.9b in grid construction," *Xinhua News*, November 17, 2008, http://www.chinadaily.com.cn/bizchina/2008-11/17/content_7211671.htm.

35 BIPV typically relies on "thin film" PV technologies that are non-silicon based, and thus will not benefit directly from the decline in polysilicon prices. However, BIPV will benefit from the projected long-term trend of increasing market expansion of thin-film relative to silicon-based PV.

36 McKinsey Global Institute, *Preparing for China's Urban Billion*, March 2008.

37 "Official: "Relative overcapacity" in energy likely to persist," *Xinhua News*, December 15, 2008.

38 Amory Lovins, et al., Small is Profitable (2002), p. 3.

39 Zhao Yuwen, "Chapter 7: 2008 Report on Photovoltaic Industry Development in China," Li Hejin and Zeng Shaojin, eds., Annual Report on China's New Energy Industry, 47-67, p. 63.

[40] Personal communication with Justin Wu, a wind industry analyst at New Energy Finance, February 5, 2009. According to Mr. Wu, there have been reports that some wind developers in China have had to hire foreign technicians for operations and maintenance work due to a shortage of local engineers.

[41] Li Jing, "Environment: 350b yuan to pour into environmental industry," *China Daily*, November 27, 2008, http://www.chinadaily.com.cn/bizchina/2008-11/27/content_7262855.htm.

[42] See Xiao Wan, "Govt offers 10b yuan in subsidies for power sector," *China Daily*, January 20, 2009, http://www.chinadaily.com.cn/china/2009-01/20/content_7411396.htm.

[43] See State Council Information Office, China's Energy Conditions and Policies, December 2007 ("The price mechanism is the core of the market mechanism…It has propelled electricity tariff reform to ensure that electricity generation and selling prices are eventually formed by market competition, with the electricity transmission and distribution prices being supervised and controlled by the state.") and the Energy Law of the People's Republic of China (Draft for Public Comments), Article 87 - The Price Formation Mechanism ("The State establishes the energy price formation mechanism that combines market regulation and government control but is led by market regulation, according to a formula that best indicates the supply-and-demand situation, the scarcity of resources, and the cost of environment damage.").

[44] Zhang Qi, "Govt may raise power rates soon," China Daily, September 13, 2008, p. 10.

[45] For a good survey on renewable energy feed-in tariffs as applied broadly in Europe and to a more limited extent in the United States, see Wilson Rickerson and Robert C. Grace, "The Debate over Fixed Price Incentives for Renewable Electricity in Europe and the United States: Fallout and Future Directions," February 2007.

[46] See, David Cyranoski, "Beijing's Windy Bet," Nature 457, no. 22 (January 2009): pp. 372-74. Cyranoski describes how the rosy annual growth in installed capacity in China's wind sector belies what are fairly disappointing wind power generation figures cause by various factors, including poor quality of domestically manufactured wind turbines.

[47] The Medium-to Long-Term Renewable Energy Development Plan released in September 2007 required grid companies and certain power companies to source fixed amounts of renewable energy power by 2010 and 2020. These so-called Market Mandated Share (MMS) requirements were absent in a subsequent and presumably superceding document, the 11th Five-Year Plan for Renewable Energy Plan, released in March 2008. The fate of the MMS remains unclear

[48] Liang, "guangfu fadian jia chengben dafu xiajiang."