China’s Solar Policy:
Subsidies, Manufacturing Overcapacity & Opportunities

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Executive Summary

In just three years, China's production of solar photovoltaic (PV) cells and modules has grown from 1 gigawatt (GW) to 20 GW, and its industry now accounts for more than 50 percent of the global market. At the same time, prices for solar modules decreased to $1.40 per watt at the end of the second quarter 2011 and are rumored to be encroaching upon $1 per watt.

The goal of the George Washington University Solar Institute is to conduct research on the economic, technical, and public policy issues associated with solar energy. The Institute requested support in light of China's increasingly important role in the solar market. This research identifies the drivers behind China's recent rapid advance in solar PV manufacturing and discusses the sustainability of China's industry in the short term. Our methodology included:

- A literature review and market research.
- Review of financial filings of eight Chinese companies and four non-Chinese companies
- Interviews with experts from national labs, organizations, and solar manufacturers.
- An evaluation of Chinese market share and excess capacity under several scenarios, including higher domestic demand and a US tariff on Chinese PV imports.

Our literature review identified drivers of China's solar expansion, including its manufacturing policies, the economic opportunity in a rapidly expanding market, and China's general manufacturing strengths. The policies supporting a solar industry include readily available credit at low interest rates, tax incentives, low rates for land and raw materials, guaranteed price mechanisms for solar projects and rebates on tax and interest. China's large loans and manufacturing policies have supported its quick rise to the top of global PV production, and new deployment policies are beginning to expand its domestic market.

We conclude that in the near future, the sustainability of China's PV industry and the speed of its growth will depend on how well it addresses overcapacity and captures domestic demand.

Risks to the future sustainability of China's PV manufacturing sector include increasing transportation costs, dependence on a single type of PV technology, dependence on exports, changes to exchange rates, import restrictions on Chinese products and inflation of labor rates. The Chinese companies included in this analysis are planning to address some of these risks by increasing automation, reducing costs to guard against exchange rate changes, and seeking opportunities in the domestic market. Further actions could include: increased presence in new markets, such as Brazil, South Africa, and Australia, and entry into other PV technology markets, including thin film.

1. Introduction

Changing policy incentives in Europe, rapid increases in solar manufacturing in China, and severe increases and then drops in prices of raw material inputs have affected the growth of the global solar business. Because of the speed with which China grew to become the largest solar photovoltaic (PV) manufacturer in only a few years, critics have questioned the legality of its subsidies and the future sustainability of its industry.

The George Washington University (GWU) Solar Institute's goal is to be a premier research facility for economic, policy, and technical research on solar. In light of China's important role in solar today, this paper provides the GWU Solar Institute with background and analysis of China's policies and the characteristics of its solar manufacturing industry. The main questions we address are: what are the drivers behind China's recent rapid advance in solar PV manufacturing? Can China sustain its current share of the PV manufacturing market? What are the implications of China's short-term industry sustainability for the global market?

This introduction provides an overview of recent trade action by US manufacturers against Chinese manufacturers and an introduction to the PV supply chain. Subsequent sections include the status of the global and Chinese PV markets, Chinese policy, drivers behind China's manufacturing success, and a discussion of several hypothetical market scenarios.

Why now? - US manufacturer petitions against China's solar policy

On October 19, 2011, a group of solar manufacturers led by SolarWorld submitted a trade petition to the US Department of Commerce (DOC). The petition alleges that China is unfairly subsidizing its solar manufacturing industry with cash grants, multi-billion dollar preferential loans, raw material discounts, tax incentives, and currency manipulation (CASM, 2011a). SolarWorld (2011b) seeks to establish that Chinese companies could not possibly have production costs low enough to be selling modules and cells at their current prices in the US. SolarWorld and Coenergy filed a similar complaint in August 2009, asking the German government and the European Union (EU) to begin an antidumping investigation. According to Lewis (2011), the EU has not initiated an investigation.

On December 2, 2011 the International Trade Commission (ITC) voted that there were indications of damage to the US solar industry (Associated Press, 2011). In March and June 2012, the DOC will make final determinations on whether to levy an antidumping duty and/or countervailing duty.[1] Some US companies have also responded against the petition (Sun Edison LLC, 2011), due to a perceived greater threat to the solar industry from a penalty on China than China's policies. Jefferies (2011) predicts that the petition would lead to higher module prices – dampening demand, although Chinese companies could circumvent the tariff by using other countries. In an interesting twist, Chinese manufacturers responded to the SolarWorld petition by asking the China Ministry of Commerce to start an investigation against the US into dumping and illegal subsidies (Juan, D. & Oingfen, D., 2011).

[1] A countervailing duty is put on imports to counteract illegal subsidies.

This is not the first instance of trade disputes around renewable energy. In October 2010, the United States launched an investigation into the practices of China in green technologies – due to a petition from the United Steelworkers. This petition claimed that export restraints, prohibited subsidies, discrimination against foreign companies and imported goods, and domestic subsidies were inconsistent with World Trade Organization policies (USTR, 2010). Specifically, this petition included special funds for manufacturing, export product funds, and financing through export credits by China's Export-Import Bank (Eisen, 2011). The USTR decided in December 2010 not to take action on the solar components of this petition, due to lack of evidence (Lewis, 2011).[2]

Solar photovoltaic technology and supply chain

Solar technology is commercially available and reliable. It causes less air pollution and greenhouse gases than burning fossil fuels, and contributes to energy security.

Solar PV technology creates electricity when solar photons strike a solar cell – a thin sheet of semiconductor material. Flowing through the cell, the light creates a voltage and electricity is generated (Arvizu et al., 2011). This analysis centers on mono- and multi-crystalline silicon (c-Si) solar PV technology. Mono- and multi- c-Si PV composed 80% of the global market in 2009, including almost all of Chinese production, and remains the predominant technology in 2011 (Arvizu et al., 2011; Goodrich, 2011).

The c-Si PV supply chain has five basic steps. The first step is to convert mined silicon to "solar grade" silicon with purity levels greater than 99.9999 percent (EPIA, 2011c). From the high purity polysilicon, ingots are formed. The ingots – long, solid blocks – are sliced into wafers. The fourth step is to transform the wafer into a solar cell. Multiple solar cells are assembled and coated to create a module (EPIA, 2011c). Figure 1.1 illustrates each step along with the percentage of the total market accounted for by Chinese manufacturers in 2010 (Greentech Media (GTM) Research, 2011).

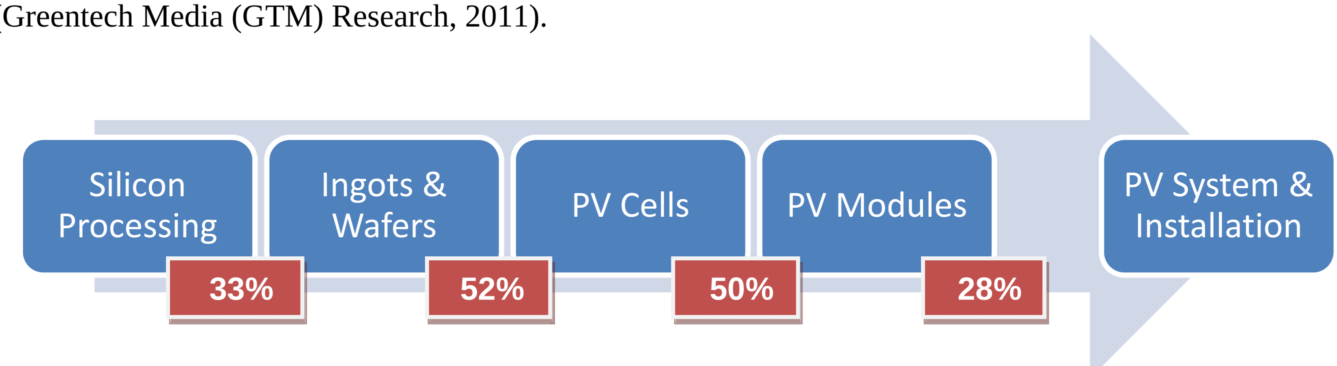

Figure 1.1: Mono- and Multi- C-Si PV and China percentage of the market in volume or total megawatts (Source: author derived from multiple sources, including Lewis, 2011; EPIA, 2011b; and GTM Research, 2011).

[2] The pressure from the petition led to China removing local content requirements for wind technology.

China's industry initially specialized in downstream PV production – creating solar cells and assembling modules (Lewis, 2011). PV cells and module manufacturing can be ramped up quickly by purchasing turnkey lines. China then increased its ingot and wafer manufacturing (Lewis, 2011). Chinese companies have limited activity in PV system and installation, as domestic demand was historically low.

2. Methodology and Research Approach

In this study, we addressed our research questions through an extensive review of peer-reviewed literature, industry association reports, news releases, and market analyses, as well as expert interviews. With this background, we tested the results of our review against the financial filings of major Chinese and non-Chinese companies and applied the drivers we identified to two hypothetical scenarios for China's industry.

For the literature review, we examined peer-reviewed articles, news articles, reports from industry and other associations, and documents submitted to the ITC as part of the SolarWorld petition. The review included current trends in the global PV market, the increased role of China in PV manufacturing, China's solar manufacturing characteristics, and Chinese PV policies. For the market research, we identified sources on current market trends in the solar PV industry, manufacturing and deployment numbers, market share of Chinese manufacturers, and future projections. These sources include the European Commission Joint Research Centre, European Photovoltaic Industry Association, Renewable Energy Policy Network for the 21st Century, and International Energy Agency. We also conducted a series of interviews, including with Dr. William Wallace from the National Renewable Energy Laboratory and a representative from First Solar, a major US solar company.

The literature review, market research and interviews provided the context for our analysis. We selected the eight largest Chinese PV manufacturing companies in 2010 and four non-Chinese companies. The eight Chinese companies accounted for 81 percent of the Chinese market and 40 percent of the global market in 2010. From the companies' annual and quarterly financial reports, we gathered data on manufacturing capacity, shipments, interest rates on loans, earnings per share, and degree of integration (i.e. at how many phases of the supply chain a company produces).

For the analysis of our findings, we identified two possible scenarios that could affect current market trends for China's industry: a large change in domestic demand and a tariff on Chinese imports into the United States. We projected how these two scenarios could have an effect on China's industry using the market characteristics and literature-derived drivers.

Our research was constrained by limits on available data. We only considered the largest Chinese manufacturers, which could have different characteristics than smaller companies. We did not consider changes in the third quarter 2011, as companies did not begin to release that information until close to the conclusion of this project. We made intentionally conservative estimates in evaluating the scenarios, as discussed in the scenario section. We were not able to interview individuals with non-US perspectives, which may bias the results of the research. We supplemented this gap by reviewing submissions of the China Chamber of Commerce to the ITC.

3. Chinese and Global PV Market Trends

In 2011, prices for solar PV dropped, Italy and Germany cut back on incentives, there was a slower increase in demand, and manufacturing capacity increased out of sync with the trends in demand. This section outlines trends in installed PV capacity, market size, manufacturing capacity, prices, vertical integration, and input (polysilicon) markets.

There is some uncertainty in estimates of both the global installed capacity of solar and its manufacturing numbers. Small off-grid systems in rural areas do not have reliable installation rates (Werner, Gerlach, Adelmann, & Breyer, 2011), and there are country-specific differences in accounting for production, including inconsistencies between counting a unit when it is produced or when it is shipped.

Installed capacity

Estimates of current global installed PV capacity vary substantially. Werner et al. (2011) estimate installed capacity between 34.9 GW and 41.5 GW as of the end of 2010. The International Energy Agency (IEA) (2011a) presents a range of 18 to 25 GW. The European Photovoltaic Industry Association (EPIA) (2011a) estimates almost 40 GW, producing an estimated 50 terawatt-hours of electrical power per year. This is approximately 0.25 percent of the total amount of electricity produced globally in 2008 (IEA, 2011b).

EPIA (2011a) reports that China's cumulative installed PV grew from 68 megawatts (MW) in 2005 to 893 MW in 2010. Figure 3.1 shows the total global installed capacity by region.

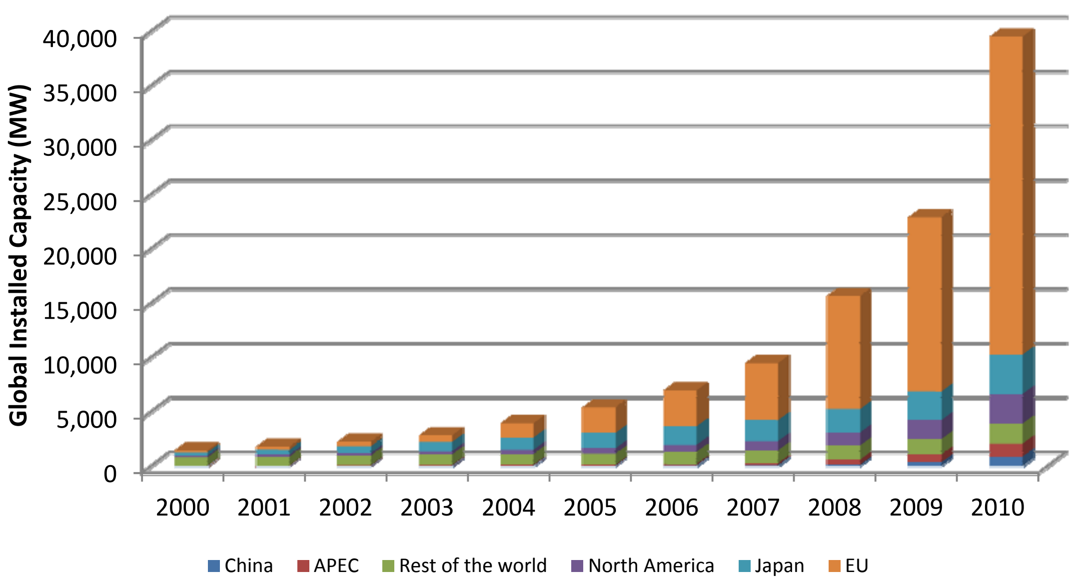

Figure 3.1: Global total installed capacity by region (Source: EPIA, 2011a).

Market size

The annual market for solar more than doubled between 2009 and 2010 (EPIA, 2011a). For 2011, estimates of total market range from 21 to 24 GW (Mints, 2011b; Osborne, 2011b), which is a 44 percent increase from the year prior.

The four largest Chinese companies (Trina, Yingli, JA Solar, and Suntech) have transitioned from producing very little to almost 2 GW each in just five years (Goodrich, 2011). In 2008, China became the largest solar manufacturer (JRC, 2011)

In 2010, China contributed 50 percent of total world PV shipments (IEA, 2011a). Figure 3.2 shows China's dominance in manufacturing supply and comparatively small role in installing PV domestically.

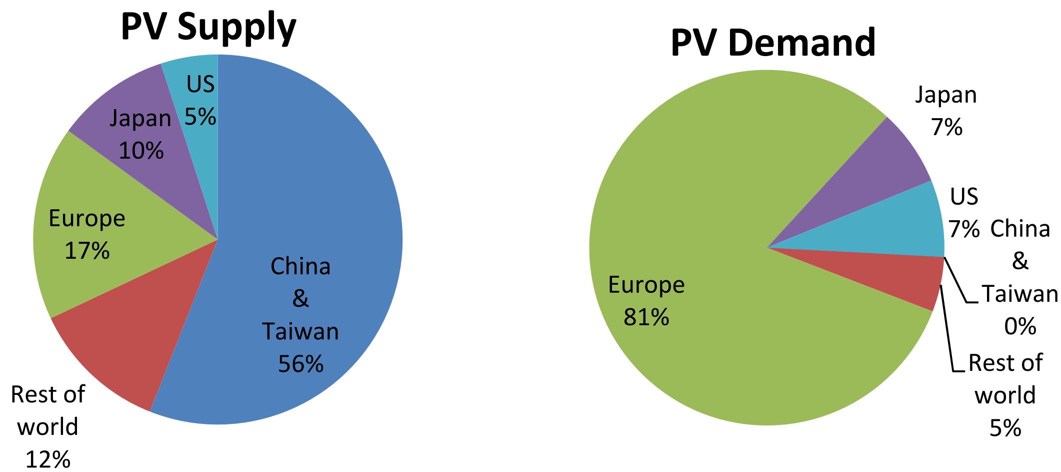

Figure 3.2: Global 2010 supply and demand percentages (Source: Mints, 2011a).

China's domestic market

China exports 90 percent of its PV products to other countries (Algieri, Aquino, & Succurro, 2011). It shipped 7.5 GW in 2010 and installed 500 MW domestically as shown in Figure 3.3 (IEA, 2011a).

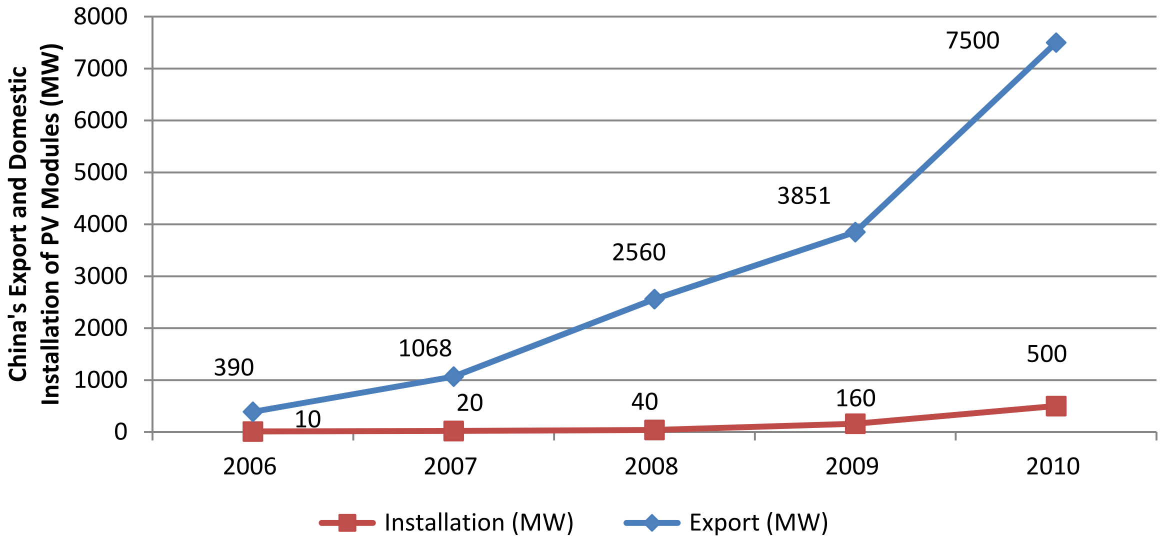

Figure 3.3: China's export and installation of PV modules (Source: IEA, 2011a).

China does have abundant solar energy resources (Liu, Wang, Zhang, & Xue, 2010), with more than 60 percent of its land area having abundant solar radiation as shown in table 3.1 (kWh/m2) (China Environmental Science Press, 2007).

Table 3.1: Solar Energy Resource Distribution in China (Source: China Environmental Science Press, 2007)

Category	Annual Solar Radiation (kWh/m2)	Percent of total area (%)	Areas
Most Abundant	≥ 1,750	17.4	Tibet, south Xinjiang, Qinghai, Gansu, and West Inner Mongolia
Very abundant	1,400–1,750	42.7	North Xinjiang, Northeast China, East Inner Mongolia, Huabei, North Jiangsu, Huangtu Plateau, East Qinghai and Gansu, West Sichuan, Hengduan Mountain, Fujian, South Guangdong, and Hainan
Abundant	1,050–1,400	36.3	Hill areas in Southeast, Hanshui river basin, West Guangxi
Normal	< 1,050	3.6	IV: Sichuan and Guizhou

Although the country is rich in solar resources, the provinces that receive the most sunlight are predominantly rural and not well connected to the national power grid (Junfeng, Sicheng, Minji, & Lingjuan, 2007; Zhang, Lior, & Jin, 2011). The high prices of PV systems, small markets, and inconsistent grid connection standards have also been constraints on China's PV use (Zhao, Zhang, & Zuo, 2011).

Comparison of Chinese and non-Chinese companies

We analyzed annual and quarterly financial reports to take a closer look at eight of the top Chinese PV manufacturers. We compared these companies to four prominent non-Chinese manufacturers using multiple financial indicators including capacity utilization, average selling price, vertical integration, gross margin, debt-to-equity ratio, and real interest rates. Table 3.2 summarizes our findings for several of these indicators.

Our analysis was limited because third-quarter 2011 data were not yet available. It was often necessary to rely on 2010 data, which do not reflect the important market developments that have occurred in the past year. For example, many companies are cutting their 2011 shipment projections, which may mean that the capacity utilization figures we report in Table 3.2 overestimate actual utilization rates.

An additional limitation is that data were not reported consistently across all companies. Some firms reported cell and module capacity separately, for instance, while others reported a combined total. Although some companies reported interest rates, it was necessary to calculate interest rates for those that did not.

Finally, the validity of the conclusions we have been able to draw is restricted by the small number of companies sampled. While the eight Chinese firms considered represent approximately 81 percent of the Chinese market, we did not consider the hundreds of smaller companies that account for the remaining 19 percent. The four non-Chinese case studies should likewise not be considered representative. Full summary tables are in Appendix B.

Table 3.2: Selected financial indicators for eight Chinese and four non-Chinese PV manufacturers (Source: company annual and quarterly financial reports; company websites). (NA: Not readily available from public sources)

Company	2011 Q2 Average Interest Rate (%) *	2011 Q2 Gross Margin (%)	2011 Q2 Debt/Equity Ratio	Estimated Capacity Utilization (%)	
				2010	2011 (as of Q2)
JA Solar	-1.4	0.0	1.15	70	60
Trina Solar	-2.2	0.2	0.92	88	93
Jinko Solar	-2.9	25.4	2.09	45	65
Canadian Solar	-2.1	13.2	2.87	NA	61
Suntech	-0.9	4.1	2.27	87	92
China Sunergy	-2.1	2.6	2.29	73	40
Yingli Green Energy	0.0	22.1	1.54	NA	NA
Hanwha SolarOne	-1.3	7.8	0.80	80	67
First Solar (USA)	0.8	36.6	0.34	94	81
Solarworld (GER)	4.0	13.3	1.29	87	70
Q-Cells (GER)	2.2	NA	2.48	NA	39
SunPower (USA)	NA	3.3	1.23	NA	NA
Average: Chinese	-1.6	9.4	1.74	74	68
Average: Other	2.3	17.7	1.34	91	63

* Real interest rates calculated from June 2011 consumer price indices (June 2010 base) (Source: National Bureau of Statistics of China, US Bureau of Labor Statistics, Federal Statistical Office of Germany).

Manufacturing capacity

As global production has grown rapidly, so has manufacturing capacity, with gigawatts of capacity remaining idle. EPIA (2011a) reported that global production capacities were substantially higher than 2010 demand for PV, total modules capacity was 30 to 32 GW, but that the total market for modules was possibly only as high as 18 GW. This pattern continued in 2011. IMS Research found that since January 2011, demand for solar has increased 19 percent, but manufacturing capacity has grown 54 percent, and estimates that at the end of 2011 there will be twice as much capacity as demand (Stuart, 2011).

New PV manufacturing capacity in China increased from just over 1 GW to 20 GW in three years, and China intends to grow manufacturing capacity to 40 GW in 2012 (JRC, 2011).

This is almost as much capacity as there was cumulative installed solar at the end of 2010, and higher than the global module production capacity reported by EPIA (2011a).

To estimate the extent of Chinese firms' excess capacity (i.e., capacity in excess of production), we make several assumptions. When companies reported module, cell, and wafer/ingot capacity separately, we assume that production at earlier phases of the supply chain would not be sold outside of the company, but rather allocated to internal downstream production to the extent possible. We regard total capacity, then, as the sum of capacity at the module phase and any additional capacity at upstream phases. Furthermore, we consistently assume that reported shipments were equivalent to actual production for a given period.

Many of the estimates reported by companies include only the production capacity that they have formally announced. This could include production lines that are not operational as well as expansions unrealized (EPIA, 2011a). Excess capacity may also indicate that there will be some consolidation on a short-term basis as some companies drop out as the market matures.

As reported in Table 3.2, we find that our chosen Chinese companies' 2011 capacity utilization as estimated in the second quarter did not differ markedly from that of the non-Chinese firms. The Chinese manufacturers appeared to be producing in 2011 at a slightly higher rate relative to their capacities (68 percent) than did non-Chinese companies (63 percent). In 2010, by contrast, non-Chinese firms produced at nearly full capacity. The increase in non-Chinese overcapacity may be at least partially attributable to an increase in Chinese shipments, if Chinese firms are indeed outselling their global competitors, in addition to a lower than expected demand in 2011.

Some companies have taken action in response to overcapacity. First Solar delayed the launch of a facility in Vietnam. SolarWorld, REC, Solon, and PV Crystalox have all announced shutdowns, and other companies (e.g., Solyndra and Solon) have declared bankruptcy (Stuart, 2011). Suntech, the second largest Chinese manufacturer and world's largest solar module manufacturer, announced it will put capacity expansions on hold in 2012 (Osborne, 2011a).

The China Chamber of Commerce for Import and Export of Machinery and Electronic Products (2011a) predicts that excess capacity in China will be absorbed by demand growth from other markets in China and the Asia Pacific. However, China will have to install between only six and seven gigawatts on average annually to meet its target for domestic installed capacity of 50 GW by 2020 (Sichao, 2010; Pew, 2011). This level of demand is far from sufficient to resolve Chinese firms' overcapacity by itself.[3]

As we will discuss subsequently,[4] China's government appears to be actively promoting consolidation of the country's PV industry. Should a significant number of smaller firms drop out, China's overcapacity could be substantially reduced.

Prices

The marginal cost of a module captures raw materials, labor, and capital equipment. Declining prices have supported the growth of the PV market, accelerated by support mechanisms, technological progress, and increased production efficiency (EPIA, 2011c).

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[3] For a more extensive discussion, see Section 6: Projecting China's Market Share and Overcapacity.
[4] See Section 4: China's Policies.

The decline in module prices has recently accelerated. Mints (2011b) reported that mid-year c-Si prices were at $1.40 per watt and decreasing. Average selling prices for a specific company may vary according to purchase sizes and supply chain integration.

Figure 3.4 depicts the average reported or calculated selling prices of the eight Chinese and four non-Chinese companies whose financial statements we analyzed. These prices were either stated or calculated from solar module revenue and total shipments. Average selling prices for the Chinese firms in 2011 appear comparable to those of their non-Chinese counterparts.

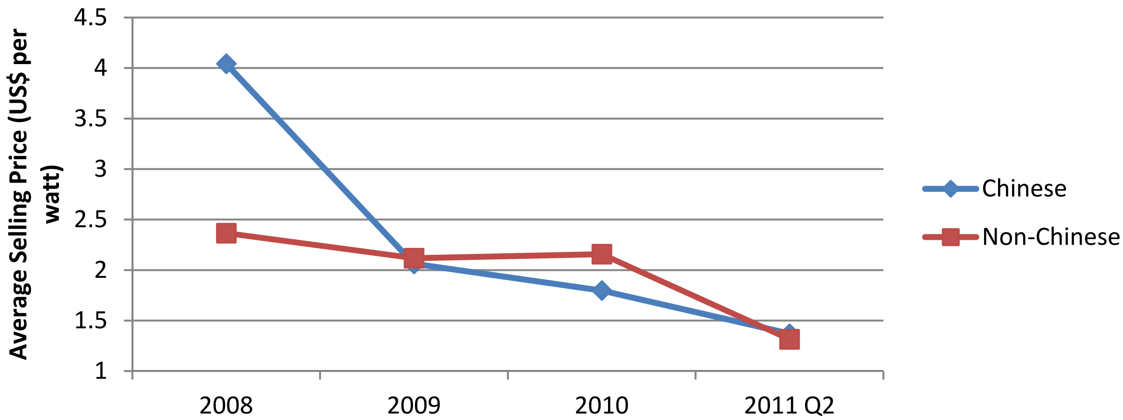

Figure 3.4: Average selling price for sample of Chinese and non-Chinese companies (Source: Author derived from company annual and quarterly financial reports, including total module revenue and total shipments).[5]

It is possible that, by undercutting the prices of non-Chinese companies and dramatically increasing supply, Chinese companies have driven global prices down to their current level. As listed in Table 3.2, the gross margin in the second quarter 2011 for the chosen Chinese companies was somewhat lower than the non-Chinese companies.

However, it may also be that low prices are a natural consequence of learning and innovation on the part of manufacturers. Many analysts have observed that solar PV has a "learning factor" of 20 percent (Arvizu et al., 2011), which means that every time volume doubles, the price decreases 20 percent (EPIA, 2011b). Prices in the 1990s, for instance, were greater than $6 per watt. However, Zweibel (private communication, 2011) observes that the recent rate of price reduction seems to be markedly in excess of what could be expected from "learning factor" alone.

Other factors were identified by Sun Edison LLC (2011) as part of its argument against SolarWorld's petition to the ITC, including the decreasing price of polysilicon and competition from thin film.

It is clear that over capacity in both purified silicon feedstock and module manufacturing have played a key role in the recent major price declines.

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[5] First Solar is included as a non-Chinese company, although it produces thin film cadmium telluride PV rather than crystalline silicon PV.

Vertical Integration

The majority of the Chinese companies we analyzed state in their annual reports that they are pursuing greater vertical integration to realize cost savings. Although these firms spend more time in their financial statements discussing vertical integration than do their global competitors, it appears that the non-Chinese companies are also active at multiple phases of the PV supply chain. SolarWorld, in particular, is involved in all stages of the supply chain, from polysilicon processing to module production (Table 3.3).

Table 3.3: Areas of production for eight Chinese and four non-Chinese PV manufacturers (Source: company annual and quarterly financial reports; company websites).

Company	Polysilicon	Wafers/ingots	Cells	Modules	Systems
JA Solar	x	x	x	x	In development
Trina Solar		x	x	x	Part of strategic plan
Jinko Solar		x	x	x	
Canadian Solar		x	x	x	x
Suntech		x	x	x	x
China Sunergy			x	x	
Yingli Green Energy	x	x	x	x	
Hanwha SolarOne	x	x	x	x	
First Solar (USA)	NA	NA	x	x	x
SolarWorld (GER)	x	x	x	x	x
Q-Cells (GER)			x	x	x
SunPower (USA)		x	x	x	

Note: First Solar manufactures cadmium telluride thin film, in contrast to the other companies producing c-Si modules. They are listed as NA for polysilicon, ingots and wafers as these processes and materials are not used.

Most of the selected Chinese PV module and cell manufacturers do not seem to be active in polysilicon processing. However, it has been alleged that state-owned Chinese polysilicon processors are selling polysilicon to downstream manufacturers at reduced prices (SolarWorld, 2011b). Although vertical integration across the entire manufacturing supply chain may be an advantage in the solar PV market, Chinese manufacturers are at risk of increased transportation costs if their PV module assembly is located in China alone and not in the country where the PV is installed. PV modules are more expensive to ship than their component parts, PV cells (Goodrich, 2011; Science Friday, 2011).

Raw Materials – Polysilicon

Prices for solar modules have decreased steadily since the 1980s, with some temporary changes from approximately 2004 to 2008 driven by an increase in raw material costs due to undersupply of polysilicon. Silicon is the largest single cost to manufacture a c-Si solar PV module. Roca and Sills (2011) cite polysilicon as a quarter of the cost of a finished solar panel, but values from individual solar companies producing modules vary depending on whether they own polysilicon manufacturing and the terms of their supply contracts.

In 2010, China grew to be the largest polysilicon producer, with one third of the total market, in front of the US (25%), South Korea (16%), and Germany (15%) (GTM Research, 2011). Each company we evaluated mentions the changing price of silicon as a risk to its business.

One of the grounds for SolarWorld's (2011b) petition is that China is illegally subsidizing its PV industry through lower-than-market polysilicon prices for its own producers. SolarWorld (2011b) supports its argument by claiming that market prices are $64 to $87 per kilogram globally but $30 per kilogram in China. In its 2010 annual report, Trina Solar cited long-term contract prices of $57 per kilogram and spot prices of $85 per kilogram. In November 2011, Bradsher (2011) cited global prices of as low as $33 per kilogram. It is not clear whether the major Chinese manufacturers were receiving different prices than the world spot price; however, the global prices cited by Bradsher (2011) are closer to the prices SolarWorld (2011b) alleges Chinese companies are receiving than to the cited global prices.

4. China's policies

The solar industry across countries is heavily influenced by public policy, in the form of feed-in-tariffs[6] (FiTs) and subsidies for research and development, direct subsidies for manufacturing and deployment, as well as policies to capture the external costs of fossil fuels to the environment and climate.

This report focuses on policies that support PV manufacturing in China. These policies can be directly subsidizing manufacturers or support solar deployment domestically to strengthen the market for these manufacturers.

EPIA (2011c) lists four elements of a successful renewable energy policy: a clear guaranteed pricing system, clear planning and administration procedures, priority access to the grid and clear identification of grid connection responsibilities, and public acceptance. China's policies hit several of these elements, but how well the policy sets clear procedures and systems is debated. China recently rolled out a pricing system (a FiT), has procedures for planning and administration – including required quality certification of technology and integration requirements – and is improving its planning procedures.

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[6] A FiT reimburses renewable energy producers at a set price for the amount of electricity they contribute to the grid. Typical FiT's also have a guaranteed pricing structure for utility companies purchasing the power and often require grid connection (EPIA, 2011b).

The petition made by SolarWorld in October 2011 cites a total of 200 subsidies, including low rates on raw materials, tax reductions, advantageous loans, and funds towards physical assets (Juan & Oingfen, 2011). Table 4.1 shows the primary manufacturing and deployment policies described in this report.

Table 4.1: China's Solar Policy

Direct Manufacturing Policies	Indirect Deployment Policies
Preferential loans	Central government planning & goals
Tax incentives	Direct subsidies
Research and development support	Feed-in tariff
Central government planning	Local and province policy
Local and province policy	

Primary policy vehicles

Two of China's primary policy vehicles include the 2006 Renewable Energy Law (REL) and the 12th Five-Year Plan (FYP). The REL was passed in 2005. It establishes the energy authorities of the State Council as responsible for managing renewable energy development, supports in-country power generation, and requires grid enterprises to purchase renewable energy power generated within their grid and to provide grid connections (JRC, 2011). The REL set targets for domestic deployment of PV and is the framework for tax incentives and financial subsidies (Su, Hui, & Tsen, 2010).

The National Development and Reform Committee established the Renewable Energy Development fund in 2006, a product of the REL. This fund issues grants and subsidizes loan interest on PV projects and for research and development (Solangi et al., 2011).

With the REL, China established a FiT, set conditions for participating in renewable energy projected, and identified priority geographic areas. The REL was revised in 2009 and established a guarantee that all renewable energy-based electricity would be "subjected to purchases" by electricity utilities (Sichao, 2010). Table 4.2 below summarizes the primary instruments of the REL, taken from Ng (2011).

China's 12th Five-year Plan (FYP) was released in March 2011, but has not been fully disclosed. Its goals are to encourage domestic consumption, develop the service sector, increase higher value-added manufacturing, conserve energy, and clean up the environment (U.S.-China Economic and Security Review Commission (ESRC), 2011). For renewable energy, this plan sets a goal of 11.4 percent of total energy coming from non-fossil fuels in 2015 – up from a 2020-goal of 8.3% in 2010 (US-China ESRC, 2011). Alternative energy is also designated in FYP as one of China's seven strategic emerging industries, and we assume this has pronounced effects in terms of government support. The 12th FYP builds upon and expands the investment spurred by the 11th FYP.

Table 4.2: Major Policy Instruments in China’s 2006 Renewable Energy Law (Ng, 2011)

Instrument	Specification
National renewable energy target	Establishes strategic position of renewable energy; identifies scale of market development, types of technologies needed, and priority locations for development.
Grid-connection priorities	Grid companies must accept all power generated by renewable energy with price fixed by government and are required to build systems to integrate renewable energy with grid.
Classifying tariffs for renewable energy power	Government determines price based on average cost, cost with advanced technologies, or bidding price.
Sharing costs at national level	Costs for on-grid renewable energy electricity and off-grid generators in rural areas are shared by grid consumers in whole country.
Renewable-energy special fund	Special fund covers: technology research, standards development, and pilot projects; household renewable-energy utilization projects in rural and pastoral areas; off-grid electrification projects in remote areas; renewable energy resource assessments and evaluation; establishment of localized renewable-energy manufacturing industry; special fund comes from central and local finance as balance of cost sharing.
Policies on favorable credit treatment	Financial institutions may offer preferential loans with national financial interest subsidies to eligible energy development and utilization projects; national policy banks, national banks, bilateral aid funds, inter-national multilateral aid banks, and financial organizations are able to supply favorable loans.
Policies on favorable tax treatment	Preferential tax will be given to renewable energy projects.

Direct manufacturing policies

Preferential loans

There is disagreement on the value of loans to Chinese solar companies. Interpretations on the value of loans to Chinese solar manufacturers vary from emphasis on the total availability of credit to the interest rates to the total amount of credit used. In Table 3.2, we state the real interest rates that eight Chinese companies and four non-Chinese companies appear to be paying. For those rates that were not explicitly reported by the companies, we estimate their values based on companies’ reported interest payments in the second quarter of 2011 and total outstanding long- and short-term borrowings and bonds. From our research, it appears that the Chinese firms are paying real interest rates of negative 1.6 percent on average.

By comparison, we found that the average real interest rate for the US and German companies considered was 2.3 percent, which is significantly higher. While the average nominal interest rate is about five percent for both Chinese and non-Chinese companies, this does not capture differences in inflation rates between the US, China, and Germany. This report does not delve further into the role of inflation for China’s solar industry, either in investments or loans.

Beyond a low interest rate, Chinese PV companies may be benefitting from greater access to credit. The total amount of loans available for Chinese solar manufacturers for 2010 and the first half of 2011 is reported in the range of $34 to $40 billion. Department of Energy Secretary Chu stated that the Chinese Development Bank alone provided $34 billion in credit during testimony to Congress (DOE, 2011). Some Chinese firms are replying to reports on their loans, by either citing the interest they pay or that they have not drawn down the full amount of the available credit. For example, Wesoff (2011) cites communication with Suntech, one of the top three solar companies in China, stating that the company received a $7 billion credit from the China Development Bank, although a spokesperson asserts that less than 10 percent was drawn down.

We find that availability of credit is a driver of China’s growth in the PV sector; it allowed access to funds during economic uncertainty and encouraged quick growth. This finding is supported by Goodrich (2011), who concludes that China’s availability of credit was an advantage that provided greater certainty than if these companies had sought private credit.

Tax incentives

Under the REL, eligible PV companies are exempt from value-added taxes and customs duties, and business income tax may be reduced to 15 percent (Zhao, Zhang, & Zuo, 2011; Zhao, Zuo, Fan, & Zillante, 2011; GuoKeFahuo, 2008). Further, some high tech development zones and particular provinces support additional tax incentives (REN21, 2011a).

The Chinese companies we investigated are primarily Foreign Investment Enterprises (FIEs) established in the Cayman Islands. All of the companies included changes in their tax status as a business risk. SolarWorld’s petition included supporting documents on the incentives firms received under the Enterprise Income Tax law (EIT). Under the EIT, FIEs had tax exemptions for 2 years after the first year of profitability, and have a 50 percent tax reduction for the next three years (Industry Week, 2007). Any company under the EIT was grandfathered to keep its tax breaks until they expire under the Corporate Income Tax Law (CIT) in 2007. Several solar manufacturers are still benefiting from the reduced tax rate because of having established a presence before the CIT (SolarWorld, 2011b). Companies can still get similar tax holidays under the CIT in certain regions, and also for certain projects, like infrastructure (GuoKeFahuo, 2008).

Under the CIT, the FIEs (JA Solar, Jinko, Trina, and others) expressed concerns in annual financial disclosures that the new law would determine FIEs are subject to income tax over their entire operations in China. Although they are established in the Cayman Islands, their governing body is in China. China’s industries also have available tax credits of other types, such as a manufacturing tax credit (Goodrich, 2011), which reduce the effective tax rate for corporations.

Research & development support

Research and development support is provided by the central government through the Chinese Ministry of Science and Technology. It supports R&D by companies and by public research institutions (De la Tour, Glachant, & Meniere, 2011). In the 11th FYP, China provided a small amount, $18.5 million, for solar PV R&D (Lewis, 2011).

Central government planning

Lewis (2011) cites some influence of China’s central government to “pick winners” and consolidate the industry, as the sheer number of Chinese solar companies may be forcing Chinese firms to cut prices and sacrifice profitability (Marketwire, 2011, December 13). According to Yingli CFO Bryan Li, Chinese banks are tightening lending and making lists of the solar companies with which they are willing to continue to work. Such a move will likely push some smaller, less successful companies out of business (Daily & Groom, 2011, December 6) and reduce China’s excess manufacturing capacity.

A trade petition against China filed in September 2010 alleges that China also does not allow foreign companies to obtain international emissions credits for the project unless a Chinese firm holds a majority in the venture (USW, 2010), however a First Solar representative indicated this incentive is no longer in place (personal communication, December 1, 2011).

Currency

In October 2011, the US Congress considered imposing a tariff on Chinese goods due to “improper valuation” of China’s currency, which would give it an advantage in exports. In a report to Congress, the U.S. –China Economic and Security Review Commission (2010) notes the slow appreciation of the renminbi against the US dollar, and claimed the renminbi was “substantially” undervalued, subsidizing exporters. China denies it is manipulating the value of the renminbi (New York Times, 2011). SolarWorld (2011b) argues that currency manipulation is a major way by which China is supporting solar as an export business.

Export Policies

SolarWorld (2011b) found that Chinese PV manufacturers are eligible for incentives as major exporters. They state that these companies could be benefiting from policies that return income tax paid on profits that are reinvested into a FIE, which is only given to companies meeting a certain export threshold. SolarWorld (2011b) also alleges that China’s PV manufacturers are eligible for the Export Product and Research Development Fund, which provides grants for R&D activities for export industries. The DOC will determine whether solar companies are benefiting from such policies, and whether they are illegal in the first half of 2012.

Deployment policies (indirect)

China has increased its deployment incentives in recent years, from supporting pilot and demonstration projects, to subsidizing large PV projects, to creating a FiT to support renewable energy projects by guaranteeing prices for utilities with surcharges on fossil energy. China’s investment in solar has been realized in manufacturing trends, but is on the cusp of influencing domestic installations. China’s deployment policies center around developing the power grid, promoting connections to renewable sources, and providing preferential pricing schemes for renewable energy (Su, Hui & Tsen, 2010).

Central government planning

Historically, China’s deployment goals were modest. Since the 1995 Plan for National Solar PV Development, goals have increased from 0.3 GW to 50 GW in 2020 (Sichao, 2010; Pew, 2011; JRC, 2011; Hart, 2011).

Direct subsidies

China has several direct subsidy programs that support demonstration and other deployment projects. China's "Solar-Powered Rooftops Plan" provides a subsidy that covers 50 to 60 percent of the total cost of rooftop PV and building-integrated PV (BIPV) systems (Lewis, 2011). It was reduced from 2009 to 2010 from $2.32 per watt for rooftop systems and $3.09 per watt for BIPV to $2.01 per watt and $2.63 per watt respectively (Lewis, 2011).

The Golden Sun program also supports deployment by subsidizing 50 percent of investment cost for solar PV demonstration projects and 70 percent of the investment cost for off-grid PV (Lewis, 2011; Su, Hui, & Tsen, 2010). For c-Si panels, China capped the subsidy at $2.16 per watt (Lewis, 2011). Under Golden Sun, China is investing $15 to $20 billion to install 294 demonstration projects that total 642 MW of installed capacity over the next three to five years (Zhao, Shi, Chen, Ren, & Finlow, 2011; Wang, 2010; W. Wallace, personal communication, November 2, 2011). SolarWorld (2011b) alleges that Golden Sun may be indirectly subsidizing manufacturers by selecting awardees.

Feed-in tariff

The guarantee for purchase of all renewable energy is enabled by a feed-in-tariff (FiT) system. FiTs, typically, guarantee a price for all renewable energy connected to the grid. Many countries have used FiTs to stabilize markets for solar. FiTs also support large-scale applications of solar that require large up-front capital costs (Mints, 2011b).

In China, the State Council fixes a tariff for purchases of renewable energy connected to the grid. Electric utilities are then required to purchase all renewable-based electricity at the fixed price. The additional cost of renewable energy is made up for by creating a surcharge for all electricity charges (Sichao, 2010; Zhao, Zuo, Fan & Zillante, 2011). The national FiT is Chinese yuan (CNY) 1.15/kWh (approximately $0.18) for projects completed by December 31, 2011 and CNY 1.0/kWh (approximately $0.15) for projects approved by July 2011, but not completed before the end of the year.

Local and provincial policies

Provinces and local areas also provide support for manufacturing and solar installation projects. Province and local areas are more likely to support land grants or land at reduced costs. Lewis (2011) notes that some provincial governments have been reported as giving away land to attract industry. Lewis (2011) provides an example of the company Sunzone, which reportedly purchased land at one-third of the rate for industrial land. SolarWorld (2011b) alleges that Chinese manufacturers benefited from electricity rates 17 to 60 percent lower than other industries, as well as low prices for water and raw materials. A First Solar representative identified local and provincial-based policies as the most important support for Chinese manufacturers (personal communication, December 1, 2011).

5. Drivers

Based on our research, we identified three major drivers behind the impressive growth in Chinese solar PV industry. In this section we discuss each, namely, the global demand, China's governmental policies regarding the sector and its internal demand, and the structure of Chinese PV manufacturing companies.

Global demand – An economic opportunity

Rapid growth in global demand for PV products, and anticipation for future rampant growth, was an opportunity for China's manufacturing sector. The increase in global total installed capacity from 1.5 GW in 2000 to 39.5 GW in 2010 demonstrates the magnitude of this change in demand. The primary market for solar PV modules in 2010 was Europe which accounted for 81 percent of global demand. Japan and the United States accounted for 7 percent each (EPIA, 2011a). Some also believe the demand increase is tied to solar PV rapidly approaching an economically competitive level with other electricity technologies. Dan Shugar, the CEO of Solaria Corporation, believes that that time is now, with prices having decreased from $40 per watt in the mid 1970s to encroaching upon $1 per watt today (Science Friday, 2011).

China was able to break into this market quickly because c-Si was a mature technology. Companies were able to purchase equipment from major manufacturers (Goodrich, 2011; First Solar representative, personal communication, December 1, 2011). Being a large player in this market serves both their economic and energy security objectives.

Public policies

The wide range of public policies initiated by the Chinese government, including the 2006 REL and the 12th FYP, are identified in this research as an important driver of China's manufacturing growth. Readily available loans, direct subsidies, tax rebates, land grants, and support for research and development together produce a significant driving force which has spurred the growth in China's PV industry. China has rapidly increased internal deployment goals from 20 GW to 50 GW of installed capacity in 2020. Increased internal demand, more export locations, and possibly increased diversity of products will allow Chinese manufacturers to diversify their markets and become less vulnerable to global market volatility.

Structure of Chinese companies

For this research, we considered the strengths of China's companies' structure and the manufacturing benefits in China outside of specific policies. We found that the structural characteristics of the leading Chinese companies are comparable to those of the largest non-Chinese companies. Our chosen Chinese firms and their select non-Chinese competitors are comparable in terms of such crucial characteristics as vertical integration and benefiting from economies of scale.

This research revealed a complex view of labor's role in China's PV manufacturing. Although wage rates are lower than in the US or Germany, some observers found a negligible influence of lower wage rates in China, especially because higher automation levels allow other producing countries to offset the labor advantages of China and because Chinese companies themselves are increasing the level of their automation (Goodrich, 2011; Science Friday, 2011). Moreover, today China might be facing inflation in wage rates, and there are lower labor rates in other regions (Goodrich, 2011). Goodrich (2011) found a negligible impact of labor costs on comparative production costs of solar PV between China and the US.

Goodrich (2011) also identifies increasing transportation costs as potentially major cost disadvantages for Chinese manufacturers. Public policy allows the Chinese producers to compete and offset transportation costs.

6. Projecting China's Market Share and Overcapacity

To gain a sense of what the near-term future might hold for China's PV production and sales, we construct a baseline projection for 2012-2018 and then vary it in two ways: first, by changing the assumptions regarding China's domestic demand, and second, by introducing a US tariff. Specifically, because we identify government policy as the primary driver behind the recent growth of China's PV manufacturing industry, we compare a baseline projection to two hypothetical policy scenarios:

1) The Chinese government successfully encourages domestic demand for solar energy such that China achieves 50 GW of installed generation capacity by 2018.

2) The US government enacts a tariff on imported Chinese PV products that causes China's share of the US market to fall to 25 percent beginning in 2012.

These projections are intended to be used for illustrative purposes only. Our intent is to provide the reader with a general impression of the relative impact that the two scenarios might have. They should not be construed as precise estimates; we make numerous assumptions, and projections in the solar market are highly variable. The following apply to the baseline and alternative scenarios:

- We assume that cell and module quantities are roughly interchangeable, since the EPIA projections (2011a) that form the basis for our calculations do not differentiate between cell and module quantities.

- We assume that the EPIA projections for demand are equivalent to the amount of PV product that will be sold, even though demand may not equal sales in reality.

- Considering the substantial overcapacity among Chinese firms in 2011, it is likely that they will not continue to build capacity at the same rate as in the past. We therefore conservatively assume a constant 10 percent annual growth rate in Chinese PV manufacturing capacity (reversing existing trends). Although firms' future decisions related to capacity growth are difficult to predict, industry consolidation is likely to slow or even pause growth.

We provide tables summarizing our projections and assumptions in Appendix C.

Baseline

Our "baseline" scenario is intended to serve as a basis for comparison against the two policy-driven scenarios we describe above. We do not consider it a reliable forecast of future trends. The scenario is based on a set of assumptions derived from current trends as of second quarter 2011:

- The baseline assumes that Chinese companies' share of global PV sales holds constant at 50 percent through 2018, subject to available capacity as projected (once again, this reverses existing trends).
- We use EPIA's (2011a) "moderate" projections for the baseline.
- Because these projections extend only to 2015, we assume that demand increases at a constant rate thereafter, equal to the difference between 2014 and 2015.
- We suppose that installed capacity increases after 2015 by an annual amount equal to the projected demand for the same year.
- We infer the total capacity of Chinese companies in 2010 and 2011 from the sum of our eight Chinese companies' estimated capacities, knowing that they composed approximately 81 percent of the Chinese cell market in 2010 (IEA, 2011a).

According to this estimate, Chinese companies are projected to experience a gradual decline in overcapacity of about 10 percentage points by 2018, as illustrated in Figure 6.1. It is possible that consolidation of the Chinese PV industry may further reduce this figure.

Scenario 1: Greater domestic demand in China

This scenario assumes that the Chinese government successfully encourages domestic demand for solar energy and achieves 50 GW of installed generation capacity by 2018. We use EPIA's (2011a) "policy-driven" projections for Chinese demand and installed capacity through 2015, and estimate 2016-2018 in the manner described above for the baseline. For the rest of the world, we continue to use EPIA's (2011a) "moderate" projections.

We also suppose that Chinese firms capture 75 percent of the domestic market's additional growth. This is not unreasonable, given China's history of favoring domestic companies. We continue to assume that China retains 50 percent of the foreign market.

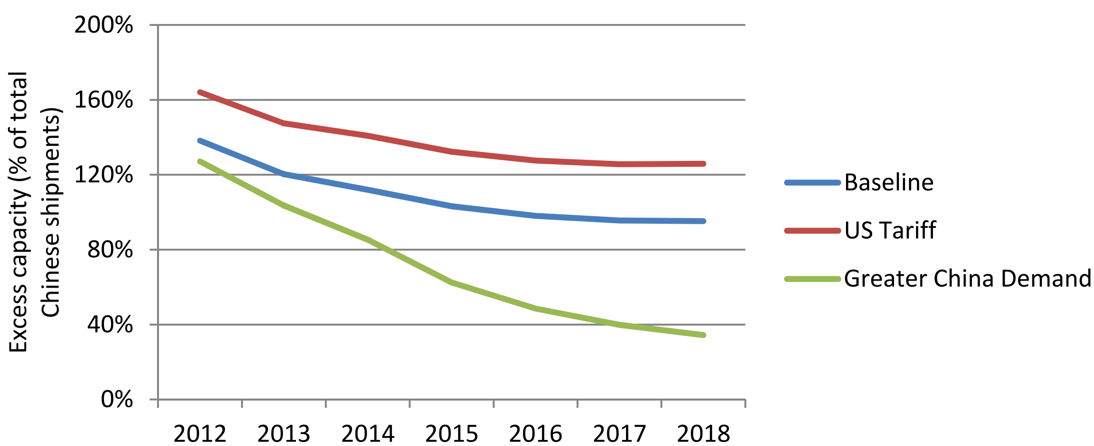

Figure 6.1: Projected excess PV capacity for Chinese manufacturers under three scenarios (Source: authors' analysis based on EPIA, 2011a; company data; and China's announced solar targets).

Figure 6.2 depicts the results of our calculations as they impact China's share of the global PV market. Under this scenario, we project a steady increase in market share from 50 percent to over 55 percent in 2018, as compared to 50 percent in the baseline scenario. A constant 10 percent annual growth rate in capacity is projected to result in a significant decrease in overcapacity of about 90 percentage points for Chinese firms as the domestic market expands (Figure 6.1), which would be considerably lower than the baseline scenario but still fail to resolve China's overcapacity problem.

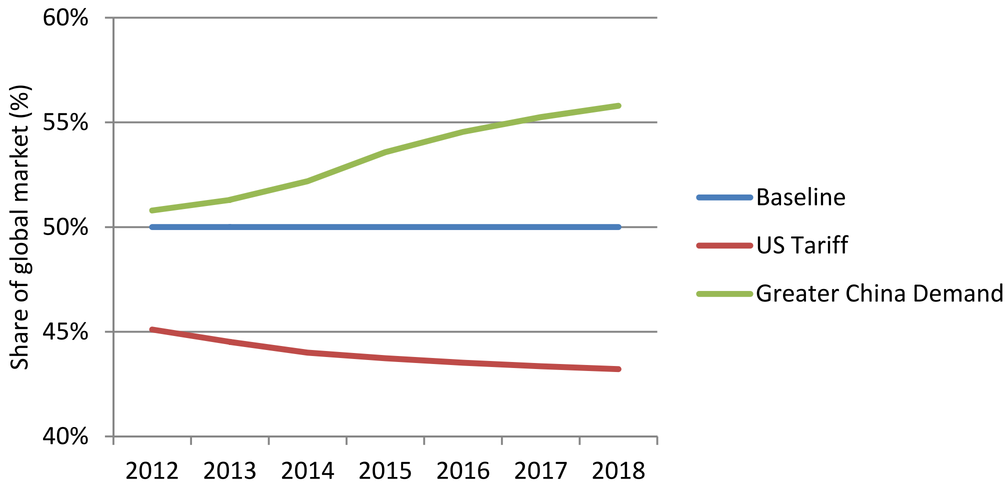

Figure 6.2: Projected Chinese share of global PV market under three scenarios (Source: authors' analysis based on EPIA, 2011a; company data; and China's announced solar targets).

Scenario 2: US tariff on Chinese PV imports

On December 2, 2011, the ITC reached a preliminary conclusion that American solar panel manufacturers are being harmed by imports. DOC is now considering a tariff of 50 to 250 percent on Chinese imports (Wald, 2011). To project the potential impact of such a tariff on China's overcapacity and share of the global market, we assume a tariff is enacted in early 2012 that immediately decreases China's share of the US PV market from its current level of 46 percent (in California) (Lewis, 2011) to 25 percent. China's share of non-US markets is assumed to remain constant at 50 percent.

It is unclear whether and to what extent Chinese firms would be able to recoup some of that loss by increasing sales to other countries other than the US. For simplicity, we assume that they do not recoup any of their lost US sales. It is also possible that, if the tariff is heavy enough, Chinese companies will circumvent the tariff in the long run by moving their US-bound production from China to other countries (Jefferies, 2011). However, this would entail either abandoning existing domestic capacity or moving the equipment, neither of which is attractive from the Chinese national strategy viewpoint. Because this is a short-run analysis, we assume that Chinese manufacturers do not act to evade the tariff.

Using EPIA's (2011a) "moderate" demand projections, we project that a tariff with the stated effect would decrease China's global market share from our 50-percent baseline to about 43-45 percent (Figure 6.2). According to our projections, China's overcapacity would increase to around 164 percent in 2012 and slowly decline thereafter to about 126 percent in 2018 (Figure 6.1), which is several percentage points higher than the baseline scenario.

As noted above, both scenarios made assumptions that reverse current trends, namely that: (1) Chinese capacity growth is held to a conservative ten percent, and (2) Chinese market share stays at 50 percent for markets outside the US.

7. Conclusions

China's policies specifically for renewable energy, and more generally for manufacturing, have supported the growth of its solar PV manufacturing industry. China's solar manufacturing policies range from central government support for high-tech enterprises in the form of readily available credit at negligible interest rates, R&D support, and reduced taxes, to local policies offering cheap land and rebates. These policies appear to have been successful in assisting Chinese manufacturers to rapidly expand over a short period of time.

We found that real interest rates on loans for the Chinese companies in our analysis were significantly lower than those for non-Chinese companies. When adjusted, all eight Chinese firms appeared to be paying negative real rates. Furthermore, Chinese manufacturers have relatively easy access to large amounts of loans. Borrowing has supported massive capacity growth, including the ability to purchase turnkey manufacturing lines in established technologies. The availability of large amounts of revolving credit also makes it possible for Chinese companies to avoid market limitations on expansion during a time of inadequate demand growth.

China quickly increased its manufacturing capacity to twice the total annual market for solar PV. This action appears out of sync with how demand is changing and well beyond what its domestic demand can absorb based on current goals. Our scenario analysis illustrates that the sustainability of China's growth in solar depends on how well China addresses overcapacity and develops and captures its domestic demand. The literature we reviewed does not reflect agreement on how the current problem of overcapacity in the solar market will be resolved. Some of the possible solutions are consolidation of market players, firms shutting down production assets, or the market growing enough to match the manufacturing capacity trends. The manner in which overcapacity is resolved will impact US manufacturers and the prices US consumers receive.

China's future sustainability may be adversely affected if it fails to diversify its markets by capturing demand outside Europe and the US, and if it fails to invest in PV technologies other than c-Si. China's policy has been very successful in growing an established technology, but is not supporting innovation at the level of other countries (First Solar representative, personal communication, December 1, 2011; Goodrich, 2011). China's policy has focused on profits rather than innovation (Shuiying, Z., L. Chi, and Q. Liquiong, 2011). This policy may be creating an artificially low price for c-Si technology that is inconsistent with actual production costs.

Other potential risks include currency inflation (Jefferies, 2011), changes to exchange rates (Goodrich, 2011), and inflation in labor wages. The Chinese companies included in this analysis are planning to address some of these risks by increasing automation levels, reducing costs to guard against exchange rates, and seeking opportunities in the domestic market. Further actions could include: increased presence in new markets, such as Brazil, South Africa, and Australia, and entry into other PV technologies, including thin film.

Recommendations

This research identified several substantive gaps of relevance to US consumers and companies, which would contribute to the GWU Solar Institute’s goal to be a premier research facility. The GWU Solar Institute could supplement its research with an investigation into the impact on US consumers of a tariff on Chinese solar imports. We completed our research at the same time that the ITC found evidence of damage to the US solar industry. The final determinations on whether to levy a duty on Chinese imports will conclude by May 2012 for all investigations. Other research areas include the impact of increased investment by the Chinese government in thin film.

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Appendix A: Client

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Appendix B: Company production and financial figures

Company	2008	2009	2010	2011 Estimated
JA Solar	NA	Cells: 800	Wafers: 300 Cells: 2100 Modules: 500	Wafers: 785 Cells: >3000 Modules: 1200
Trina Solar	Cell/module: 350	Cell/module: 600	Cell/module: 1200 Ingot/wafer: 750	Cell/module: 1900 Ingot/wafer: 1200
Jinko Solar	NA	Ingot/wafer: 300 Cell: 150 Module: 150	Ingot/wafer: 600 Cell: 600 Module: 600	Ingot/wafer: 1500 Cell: 1500 Module: 1500
Canadian Solar	Ingot/wafer: 135 Cell: 270	NA	NA	Ingot/wafer: 250 Cell: 1300 Module: 2050
Suntech	Cell/module: 1000	Cell/module: 1100	Ingot/wafer: 500 Cell/module: 1800	Wafer: 1600 Cell/module: 2400
China Sunergy	Cell: 320	Cell: 320	Cell: 400 Module: 480	Cell: 750 Module: 1200
Yingli Green Energy	Wafer/Cell/Module: 400	Wafer/Cell/Module: 600	Wafer/Cell/Module: 1000	Wafer/Cell/Module: 1700
Hanwha SolarOne	Cell/Module: 360	Module: 360	Cell: 700 Module: 1000	Cell: 1300 Module: 1500
First Solar (USA)	Modules: 716	Modules: 1228	Modules: 1502	Modules: 2300
Solarworld (GER)	NA	Wafer: 900 Cells: 450 Modules: 500	Wafer: 1000 Cells: 775 Modules: 940	Wafer: 1250 Cells: 800 Modules: 1100
Q-Cells (GER)	NA	NA	NA	NA
SunPower (USA)	NA	NA	Cells: 590	NA

Table B.1: Manufacturing capacity (MW) (Source: company annual and quarterly financial reports; company websites) (NA: Not available readily on public sources)

Company	2008	2009	2010	2011 Q1	2011 Q2	2011 Q3	2011 Estimated
JA Solar	277	509	1463	451	402	450	1800
Trina Solar	74	399	1057	320	396	372	1775
Jinko Solar	NA	14	269	208	254	230	975
Canadian Solar	168	297	804	NA	NA	355	1250
Suntech	496	704	1572	NA	NA	NA	2200
China Sunergy	107	194	348	98	89	NA	485
Yingli Green Energy	282	525	1062	NA	NA	NA	1700
Hanwha SolarOne	173	313	798	249	206	NA	1000
First Solar (USA)	504	1113	1412	407	483	NA	NA
Solarworld (GER)	NA	578	819	185	196	195	NA
Q-Cells (GER)	NA	NA	Q3: 186 Q4: 161	284	424	NA	NA
SunPower (USA)	NA	NA	NA	NA	NA	NA	NA

Table B.2: Quantities shipped (MW) (Source: company annual and quarterly financial reports; company websites) (NA: Not available readily on public source.

Company	2008	2009	2010	2011 Q1	2011 Q2
JA Solar	-7	-29	263	72	-35
Trina Solar	61	96	311	48	12
Jinko Solar	-119	196	-22	51	36
Canadian Solar	-8	23	51	6	7
Suntech	111	86	263	32	-259
China Sunergy	-23	-10	52	4	-17
Yingli Green Energy	96	-78	210	56	58
Hanwha SolarOne	-41	-21	115	23	-11
First Solar (USA)	348	640	664	116	61
Solarworld (GER)	207	85	117	17	14
Q-Cells (GER)	NA	NA	NA	NA	NA
SunPower (USA)	-124	33	179	-2	-148
Average: Chinese	**9**	**33**	**155**	**36**	**-26**
Average: Other	**144**	**252**	**320**	**44**	**-24**

Table B.3: Net income (US$ million) (Source: company annual and quarterly financial reports; company websites)

Company	2008	2009	2010	2011 Q2
JA Solar	NA	2.02	1.74	1.03
Trina	3.92	2.10	1.75	1.46
Jinko	NA	1.85	1.85	NA
Canadian Solar	4.23	2.13	1.80	NA
Suntech	3.89	2.40	1.82	NA
China Sunergy	4.13	1.87	1.92	1.62
Yingli Green Energy	NA	NA	1.75	NA
Hanwha SolarOne	NA	NA	1.75	NA
First Solar (USA)	2.37	1.71	1.41	0.98
Solarworld (GER)	NA	2.52	2.13	1.95
Q-Cells (GER)	NA	NA	2.94	1.01
SunPower (USA)	NA	NA	NA	NA
Average: Chinese	**4.04**	**2.06**	**1.80**	**1.37**
Average: Other	**2.37**	**2.12**	**2.16**	**1.31**

Table B.4: Average selling price (US$/W) (Source: company annual and quarterly financial reports; company websites) (NA: Not available readily on public sources)

Appendix C: Scenario analysis summary tables

Scenario	Assumptions
All	• Cell and module quantities are interchangeable • Demand equals sales • China's PV manufacturing capacity grows at 10 percent annually
Baseline	• Chinese companies retain a 50 percent share of global PV sales • Demand grows according to EPIA's (2011a) "moderate" projections through 2015 and increases at constant rate thereafter • Total manufacturing capacity of all Chinese companies in 2010 and 2011 is inferred from the estimated capacities of the eight Chinese companies considered in this study
Scenario 1: Greater domestic demand in China	• China achieves 50 GW of installed generation capacity by 2018 • Chinese domestic demand grows according to EPIA's (2011a) "policy-driven" projections while rest of world follows "moderate" projections • Chinese firms capture 75 percent of domestic market's additional growth and retain a 50 percent share of global PV sales
Scenario 2: US tariff on Chinese PV imports	• US enacts tariff in early 2012 that immediately decreases China's share of US PV market to 25 percent • Chinese firms do not recoup any of their lost US sales or act to evade tariff

Table C.1: Assumptions made by authors in estimating scenarios.

	2012	2013	2014	2015	2016	2017	2018
Global PV demand (moderate)	15,335	18,240	20,855	23,930	27,005	30,080	33,155
China PV demand (moderate)	1,500	2,000	2,500	3,000	3,500	4,000	4,500
China PV demand (policy-driven)	2,000	3,000	4,500	7,000	9,500	12,000	14,500
US PV demand (moderate)	3,000	4,000	5,000	6,000	7,000	8,000	9,000
Global installed capacity (moderate)	68,175	86,415	107,300	131,255	158,260	188,340	221,495
China installed capacity (moderate)	3,143	5,143	7,643	10,643	14,143	18,143	22,643
China installed capacity (policy-driven)	3,900	6,900	11,400	18,400	27,900	39,900	54,400

Table C.2: Projected PV demand and installed capacity from 2012 to 2018 (all figures in MW) (Source: authors' analysis based on EPIA, 2011a)

	2012	2013	2014	2015	2016	2017	2018
Baseline							
China shipments (MW)	7,668	9,120	10,428	11,965	13,503	15,040	16,578
Rest of world shipments (MW)	7,668	9,120	10,428	11,965	13,503	15,040	16,578
China share of global market (%)	50.0	50.0	50.0	50.0	50.0	50.0	50.0
China manufacturing capacity (MW)	18,265	20,092	22,101	24,311	26,742	29,417	32,358
China overcapacity (%)	138.2	120.3	112.0	103.2	98.1	95.6	95.2
Greater Chinese domestic demand							
China shipments (MW)	8,043	9,870	11,928	14,965	18,003	21,040	24,078
Rest of world shipments (MW)	7,793	9,370	10,928	12,965	15,003	17,040	19,078
China share of global market (%)	50.8	51.3	52.2	53.6	54.5	55.3	55.8
China manufacturing capacity (MW)	18,265	20,092	22,101	24,311	26,742	29,417	32,358
China overcapacity (%)	127.1	103.6	85.3	62.5	48.5	39.8	34.4
US tariff							
China shipments (MW)	6,918	8,120	9,178	10,465	11,753	13,040	14,328
Rest of world shipments (MW)	8,418	10,120	11,678	13,465	15,253	17,040	18,828
China share of global market (%)	45.1	44.5	44.0	43.7	43.5	43.4	43.2
China manufacturing capacity (MW)	18,265	20,092	22,101	24,311	26,742	29,417	32,358
China overcapacity (%)	164.0	147.4	140.8	132.3	127.5	125.6	125.8

Table C.3: Projected PV quantities under three scenarios (Source: authors' analysis based on EPIA, 2011a; company data; and China's announced solar targets)