STANFORD
GRADUATE SCHOOL OF BUSINESS

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NANOSOLAR 2009

INTRODUCTION

At 12 noon, the lunch bell rang at the Nanosolar headquarters in San Jose, California. Martin Roscheisen, CEO of Nanosolar, looked up from his desk at the employees headed towards the lunchroom. Providing subsidized lunch as a perk did not fit Nanosolar's model of capital efficiency. However, he wanted to get his technology out to the market as quickly as possible and knew that keeping employees on campus, interacting with each other and focused on the company's product, would help keep everyone on task.

Since its founding in 2002, Nanosolar's innovative approach to photovoltaic solar power made it one of the most visible clean technology start-ups, and had attracted high-profile venture capital. The firm had made progress in the U.S., Germany, and France, and its prospects for growth were excellent. In particular, emerging energy markets had tremendous potential, especially China, which by 2011 or 2012 could potentially eclipse Germany in its demand for solar power. First Solar, Nanosolar's competitive benchmark, had just announced a large deal with the Chinese government to collaborate on a solar generation project in Inner Mongolia. Roscheisen knew that Nanosolar should participate in the China market, and in 2009 was devising a novel approach to this challenge.

MARKET FOR SOLAR POWER

Photovoltaics (PV) is the field of research and technology concerning the conversion of sunlight energy into electricity. As of 2009, solar power was the world's fastest-growing energy technology. Demand for PV production had been doubling worldwide every two years and increasing by an average of 48 percent annually since 2002. PV panels generate electricity and

Sara Gaviser Leslie and Professor William Barnett prepared this case as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation.

interconnect with utilities' power lines; over 90 percent of installed PV generating capacity worldwide consisted of grid-tied electrical systems.[1]

Demand for Solar Power in 2009

Worldwide demand for solar power was driven by energy prices and government policies. Solar energy often satisfied peak power needs as it produced power during the high demand hours of the afternoon. The case for solar, however, would face hurdles until it became more cost competitive. The low rates of efficiency of solar cells, steep required investments in production, and the high cost of the component materials being used to manufacture solar cells contributed to this problem. Solar prices had declined over time, however. In 1976, solar power cost approximately $2.00 per kilowatt-hour but, by 2009, prices per kilowatt-hour averaged between $0.15 and $0.40. Regardless, prices were still too high to make solar energy broadly available. While the price of solar electricity was heavily dependent on location, in general, the cost of solar far outweighed the cost of other sources of electricity, particularly fossil fuels, by multiples of three to eight times.[2] (See **Exhibit 1** for a description of costs of various energy sources.)

Feed-in-Tariffs

Governments instituted feed-in-tariffs (FIT) to make solar power more economically attractive. The FITs were an incentive structure to encourage the use and development of alternative energies. Utilities were forced to buy green power (solar, wind, etc) at government-mandated above-market rates. The actual tariff imposed typically varied depending on the type of project (ground vs. roof installation) and usually continued for 15 to 20 years, decreasing over time as solar power became more economical to produce. The tariff was typically paid for by all users of electricity through a small surcharge on utility bills.

Germany was clearly the leader in FITs, but Spain and Italy also aggressively used FITs to provide incentives for investors and developers. Spain, in 2008, had one of the highest solar installation rates in Europe and FITs to provide incentives. However, the country's FIT program was capped at 500 megawatts (MW) in 2009. The U.S., on the other hand, used stimulus packages and investment tax credits to increase demand for solar electricity. Individual states within the U.S. also implemented renewable energy portfolio standards to increase the percentage of electricity that was sourced from renewable materials.

While utilities typically invested in coal-powered plants or gas-fired power plants due to their lower cost and had little incentive to move away from these energy sources, many medium-sized companies saw great opportunities for developing solar power, whether as system integrators, installers of solar power plants, or investment firms specializing in raising funds for these projects.

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[1] Robert Kropp, "Solar Expected to Maintain Its Status as the World's Fastest-Growing Energy Technology," *Sustainability Investment News,* March 3, 2009, http://www.socialfunds.com/news/article.cgi/2639.html, (October 13, 2009).

[2] Vishal Shah, *Solar Energy Handbook*, Barclays Capital Research, May 1, 2009, pp. 63-64.

Key Markets of Consumption
Germany was, by a wide margin, the largest and fastest-growing market for solar power in the world. In 2009, it had 6,000MW of cumulated capacity and was approximately a 2.5 gigawatt (GW) market or, in dollar terms, a $12-$15 billion market. In relative terms, Europe was a 4.5GW market and the worldwide market was 5-6GW. (See **Exhibit 2** for a list of energy terms and measurements.) Approximately 75 percent of the solar installations in the world were constructed in Europe and 60-70 percent of those products were installed in Germany. But demand was changing, and China in particular was on the rise. The global market for solar power was expected to be flat in 2009 due to the economic recession, but could reach up to 7.5GWin 2010. (See **Exhibit 3** for data on the market demand for solar power.)

Supply of Solar Power

The supply of solar power was constrained by the availability of raw materials: polysilicon, engineering talent, manufacturing capacity, and access to capital. Companies along the solar system supply chain could make a choice as to where they sourced components. Of course, sourcing locally reduced the cost of shipping panels to different markets.

Solar Supply Chain
The supply chain for PV typically began with silicon, which was refined and made into ingots (standard shapes for convenient storage or further processing) and then wafers to compose the solar cells. Cell companies then either fabricated these cells into panels or subcontracted this work to a third-party manufacturer. The panels were glass sheets with frames encapsulating solar cells and were normally 2 feet by 4 feet in size. Finally, these modules were developed into complete power systems. Some companies like REC Group and Solarworld AG participated in each step along the value chain while others were involved in between one and four steps. More product differentiation existed in the areas of wafer and cell components while modules and systems were relatively uniform.[3] (See **Exhibit 4** for a solar power supply chain.)

Manufacturing and engineering solar cells required expensive engineers, and talent in this area could be hard to find. The main sources of this skilled labor were the U.S., Germany, Japan and China. China was also home to some of the most talented chemists.

Leading Technologies and Firms
As of 2008, the overwhelming industry volume of PV cells, approximately 93 percent, was in crystalline silicon (c-Si) wafers and included monocrystalline and multicrystalline silicon. The remainder, roughly 7 percent, was in thin-film solar cells. The most popular materials for thin-film cells were amorphous silicon and the polycrystalline materials of cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIS or CIGS). [4] (See the **Appendix** for an overview of these technologies.) Despite their earlier dominance, crystalline solar manufacturers such as BP Solar, Mitsubishi Electric, and Sanyo were losing their dominance to thin-film players such as First Solar, which was expected to capture more than 15 percent of the market in 2009. [5]

[3] Vishal Shah, op. cit., p. 77.
[4] SolarBuzz, www.solarbuzz.com/technologies.htm, (October 13, 2009).
[5] Vishal Shah, op. cit., pp. 338-339.

Japan and Europe were the traditional manufacturing centers for the solar industry, followed by the U.S. and China. In 2004, however, manufacturing began shifting to China and, by 2008, China was the largest solar cell producer in the world; China's Suntech, JA Solar and Yingli Green Energy produced more than 1,600MW worth of solar cells in 2008. Europe was the second-largest producer of solar cells with a 27 percent market share and 1,300MW of solar cell production in 2009. The U.S. and Japan were third and fourth with 17 percent and 15 percent market share, respectively. Despite its production activities, China was not yet a major demand center for solar. [6] China and Japan were net exporters while Europe and the U.S. were net importers of solar cells. (See **Exhibit 5** for a list of leading solar cell developers and associated market share, and **Exhibit 6** for solar module manufacturers and associated market share.)

THE STORY OF NANOSOLAR

Martin Roscheisen and Brian Sager cofounded Nanosolar in 2002, with the goal of making solar power more widely affordable. Even though 2002 represented one of venture financing's lowest points and almost a complete end to early-stage venture funding, Nanosolar became the first solar company to receive funding from blue-chip venture funds, notably Benchmark Capital and Mohr Davidow, and planned to manufacture in Silicon Valley. As the industry moved from a supply-constrained to a credit-constrained environment, Roscheisen expected that capital-efficient companies like Nanosolar would come out ahead. He predicted that Nanosolar would not need to raise more financing and would be able to fund the business from its operating cash flow.

Roscheisen, the chairman and chief executive officer, led the company's science-intensive research, product/tooling/factory development, volume manufacturing, and fundraising. Prior to Nanosolar, Roscheisen was the entrepreneur behind three successful information technology companies—eGroups, TradingDynamics and FindLaw. Together they generated $1.2 billion in shareholder value. Roscheisen holds a doctorate in engineering from Stanford University.

Sager, vice president of corporate development, managed the company's government programs, strategic partnerships, and intellectual property portfolio. Before joining Nanosolar, he led a high-growth biotechnology practice at Ernst & Young. Sager earned a PhD in biochemistry from Stanford University and completed postdoctoral work at Harvard University.

Technology

Nanosolar was unique both for its energy efficiency and cost effectiveness. Nanosolar used a printing process to deposit a thin-film, CIGS-based PV semiconductor to create an efficient, durable solar cell. This semiconductor was 100x thinner than a silicon wafer and the printing process was 10x faster than the conventional thin-film process of high-vacuum deposition. Nanosolar brought the economics of printing to semiconductor manufacturing, printing its CIGS semiconductor on low-cost conductive aluminum foil. The solar cells were lightweight, pliable, easily interconnected, adjustable, and capable of supporting up to up to 25 amps of current per cell (up to 25x more than was possible with other thin-film technology available at the time).

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[6] Vishal Shah, op. cit., p. 315.

Nanosolar's solar cell standard size was 165x135mm. (See **Exhibit** 7 for further details and an image of the Nanosolar Utility Panel.)

In order to offer the flexibility to respond to new market and product requirements, Nanosolar created solar cell units independently of solar panel units. The process of creating a solar panel unit included assembling the cells into circuits and then laminating them into panels (encapsulating the solar cells between two panes of tempered glass). A panel of Nanosolar cells included 84 cells on a panel measuring 2 square meters and weighing 69 pounds.

Electricity Conversion Efficiency

CIGS-based PV thin-films had reached sunlight-to-electricity conversion efficiencies of 19.5 percent in laboratory tests. This was far superior to other thin-film technologies and even better than most crystalline silicon technologies. SunPower, using mono-crystalline silicon, was able to convert the most sunlight into electricity, about 20 percent per panel, but the cost of the silicon was much greater than that of thin-film cells. The bulk of the crystalline silicon manufacturers, however, reached solar panel efficiencies closer to 13-15 percent.

Nanosolar's CIGS roll-printing technology resulted in efficiencies, confirmed by the National Renewable Energy Laboratory (NREL), of 16.4 percent active-area on foil. This was a world record for any *printable* solar cell.[7] Although laboratory conditions were conducive to higher efficiencies than actual installations, leadership at Nanosolar expected to be able to reach 11-12 percent efficiency with its panels within its first several years of production.

First Solar was the cost-efficiency leader in CdTe thin-film; its solar panels cost 50 percent below the other players' crystalline silicon panels and had approximately 10-11 percent efficiency. Not only would Nanosolar's panels' efficiency likely surpass First Solar's, but the manufacturing costs would also make the Nanosolar product cheaper. Nanosolar set a goal of "35/35": 35 percent gross margins and $0.35 per watt cap ex. While typical capital efficiency measures were $1 per watt and higher, Nanosolar was aiming for $0.35 per watt. (See **Figure 8** for a comparison of First Solar and Nanosolar.)

Manufacturing Efficiency

Nanosolar manufactured its solar cells in a 200,000 square foot solar cell factory at its headquarters in San Jose, California. Self-manufacturing greatly reduced the time to high yield as the company had a greater ability to supervise production in order to make process adjustments to reduce defects. As R&D drove Nanosolar's business, determining the biggest levers of R&D costs was critical for the company to manage costs and stay competitive.

Leadership at Nanosolar wanted to develop a product that was both cost-efficient and capital-efficient. Capital efficiency was a lesser-known but even more important differentiator for the company and, Roscheisen surmised, would be a key enabler of Nanosolar's success. Typically, every incremental watt a solar factory produced cost more than a dollar to put in place. Many of Nanosolar's competitors' businesses were growing by 30 percent a year or higher, but their capital efficiency and resulting margins put them into what Roscheisen called "the eternal black

[7] "High Performance Thin-Film Photovoltaics Using Low-Cost Process Technology," Nanosolar Inc.

hole for cash flow." They had to continually add capacity to satisfy growth, but their high cap ex prevented them from throwing off significant additional cash or creating meaningful returns for investors.

Meanwhile, a healthy balance sheet in this business was an important indicator of likely firm survival. In order for a company to book sales, the customer had to believe in the product and the attached warranty. As such, solar companies had to offer 25-year warranties on products. The guarantees were tied into the compensation that the utility paid over 20 years for power. As Roscheisen explained, "If you have a thin balance sheet or thin profitability, it quickly hurts your sales. You may need to lower your price points or take other measures to book sales which, in turn, hurts your profitability and creates a negative feedback loop."

Yield Management

Creating a solar cell involved several processes. A single solar cell could include multiple circuits. For the cell to work, each circuit needed to function correctly as errors could cause a lower yield of the final cell. Before Nanosolar could begin manufacturing, it worked with a small sample to reach a maximum yield. It improved this yield through analyzing the product and then adjusting the process as necessary until a desired yield level was reached. Eventually, leadership at Nanosolar expected that it could conduct some technology replication outside of California. Initially, however, Roscheisen explained that the first-generation innovation had to take place at the San Jose headquarters:

> If you locate in a lower labor cost market and it takes you two quarters longer (than if you were located close to headquarters) to get from 88 to 92 percent yield at volume, the costs more than surpass the labor cost differential. Every day, we look at manufacturing ramp schedules and keep them in synch with the yield ramp. When you ramp too quickly relative to your yield, you just burn a lot of money.

The company also felt constrained by the manufacturing engineering talent it could attract and retain. The best talent was only to be found in a few places in the world, Silicon Valley being one of them.

Business Model

Nanosolar did not work with end users of solar power, nor did it plan to compete in other areas of the supply chain beyond solar cell manufacturing. Rather, its customers were systems integrators who handled the permit acquisition, construction, system testing and project completion for solar power plants. These partners included some of the world's largest utilities and renewable power plant developers. (See **Exhibit 9** for a list of Nanosolar's strategic partners.)

The company made Silicon Valley the global hub for its solar cell production. The San Jose facility manufactured the solar cells and then transported them stacked in cell carriers, by air, to regional panel assembly sites. The panels then were assembled and stacked on pallets and shipped to project sites in 20 foot long shipping containers. Panel assembly close to project sites enabled Nanosolar to minimize its days of working capital to less than one week.

EXPANSION TO GERMANY

Germany was Nanosolar's first market to implement the hub-and-spoke model. Germany's market was attractive partly due to the German government's EEG (Renewable Energy Act) FIT policy, which was enacted in 1999 and then reaffirmed in 2004. Ten years later, solar installed capacity had increased tenfold.[8] German municipal utilities—firms with approximately 100,000 customers and small cogeneration plants—wanted to invest in solar power generation, and they saw the FIT as creating an easy entry point to produce renewable electricity very close to the consumer. They lacked the assets to invest in coal-powered plants, but could afford to offer 10-20MWof wind or other renewable power facilities. Gathering more solar electricity-generating assets was particularly attractive to these utilities since, in European countries, companies could sell green electricity at a premium versus traditionally generated electricity.

Assembly Plant

Nanosolar's U.S. plant handled solar cell process manufacturing while robotic panel assembly took place in Luckenwalde, Germany, a 30-mile train ride from Berlin. Not only did the plant bring the company closer to its largest end market, but it also minimized the costs of production. Nanosolar could reduce its working capital days to less than a week versus 30 days if product was shipped from Oakland, California.

While the panel assembly plant was located thousands of miles from Nanosolar headquarters, quality assurance was less of a concern. Nanosolar's factory was completely automated, thus providing a high degree of predictability and a low incidence of errors. This was especially important considering the guarantees that Nanosolar needed to offer to its customers.

Luckenwalde had several advantages for Nanosolar, including a high availability of talent with experience in automotive assembly. (Solar modules were assembled in several stages, similar to automobiles.) Due to the fact that Luckenwalde was located in the former East Germany, Nanosolar had access to engineering talent at costs lower than the European average. Finally, as the area of former East Germany was not as wealthy as the rest of Europe, there was public support for an assembly plant.

Customers

In order to develop its customer base, Nanosolar connected with system integrators—companies that take components and build power plants and manage contractors. Beck Energy was particularly interesting to Nanosolar as it focused on the specific components that, combined, would lower the price of the complete system. Specifically, Beck and Nanosolar worked together to maximize "balance-of-system" savings.

In addition to Beck, Nanosolar had signed contracts with several other system integrators to purchase panels from Nanosolar's German assembly plant, including EDF Energies Nouvelles and AES Solar. Nanosolar's primary market focus for its first $4 billion dollars of supply

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[8] Vishal Shah, op. cit., p. 124.

contracts was in Europe, specifically Germany, France, Italy and Spain, with a secondary focus on North America.

Financing

The U.S. and China offered manufacturing loan guarantees and/or tax credits to spur activity in solar energy. The E.U.'s model, on the other hand, was to offer basic capital grants totaling 30-50 percent of the cost of a factory's construction. Each member state had a finite amount of subsidies available, the maximum amount determined by the E.U. The subsidies were paid 50 percent by the member state and 50 percent by the E.U. When Nanosolar applied for these subsidies, it was eligible for up to a 50 percent capital expenditure subsidy on the first €25 million it spent. In return, the company had to pledge to employ 50 workers and maintain that level for three years.

THE NEXT FRONTIER

Two new markets that Nanosolar considered entering were India and China. Although the powerful sun radiation in India made that market compelling, the infrastructure was not as reliable as in China and government support was not as clear-cut. There was speculation that the U.S. and China would become larger markets for solar energy in the near future. Several of Nanosolar's supply contracts had ancillary agreements in the U.S. and Canada to complement Europe, but Nanosolar had no concrete plans as of 2009 for China and India, where multi-gigawatt markets could emerge within five years.

Solar Supply in the Chinese Market

China produced over 30 percent of the world's PV but the PV installed base, 140MW in 2008, was dwarfed by Germany. Over 98 percent of the modules produced in China were exported as of 2009.[9] In addition to numerous solar cell and panel fabricators, the country had a strong supply of Chinese engineers in the solar industry. Shanghai and Suzhou (a 45-minute train ride from Shanghai) housed sophisticated teams of engineers who understood the process of incorporating a foreign business and could serve as an interface between a foreign company and the government. China also had great chemistry talent and churned many chemistry PhDs and students with advanced engineering degrees.

Generally, China was preparing for probable technology changes in the future. Suzhou had built an entire city on a platform 2 meters high to guard against flooding and also to accommodate tubing and inserts underfoot to avoid ever having to disrupt street surfaces to repair cables or other wiring. The city was also working diligently with solar companies to build solar cell design factories. The government flew in top European architects to design a production facility and would loan capital to developers who constructed a solar power facility.

By 2009, the Chinese government had enacted both a regional FIT and national subsidies for PV installations. For instance, in eastern China's Jiangsu province, home to many PV manufacturers such as Suntech, the regional government put in place a FIT. This offered solar-generated

[9] "70% Subsidy for Solar Power," *Shanghai Daily,* July 23, 2009.

electricity from PV solar farms, rooftop projects and BIPV (building-integrated PV, or PV that is involved in the construction phase) projects built in 2009 at 2.15 yuan, 3.7 yuan, and 4.3 yuan respectively (US$0.31, $0.54, and $0.63). These prices nearly covered the costs of the project and were well below typical solar prices. FITs, cheaper raw materials, and PV technology innovation were driving down the costs of solar electricity in China; costs were estimated to have declined by 50 percent from 2006 to 2008 and were propelling solar power to become a major energy resource in China.[10]

Grid companies were generally obligated to buy all renewable electricity generated in the area of their grid. Further, in 2008, China's central government announced a stimulus package to encourage renewable energy consumption. Foreign investors hoped to capitalize on this plan but they were restricted from certain activities. For instance, a foreign investor could only hold a minority stake in a Chinese-foreign joint venture constructing or operating power grids, and typically did not have full freedom to take part in the operation of power stations using new sources of energy.[11]

Demand for Solar Power

As of 2009, it was anticipated that China would need to greatly increase its supply of energy in the future. However, renewable energy competed with cheap coal and hydropower from large dam projects. Nevertheless, China was making green power a national policy. In 2007, the government set a specific target for electricity from non-hydro renewables of 3 percent by 2010 and 5 percent (1.8 GW) by 2020, as well as a commitment to invest $200 billion in renewable energy by 2020.[12] China built its first large-scale PV project in Shenzhen in 2004, generating 1MW of PV annually and, by 2009, had PV installations in other major cities such as Beijing, Shanghai, and Hangzhou.[13]

First Solar, the leader in thin-film solar cells, announced in September 2009 that it was planning to build a 2GW solar factory and installation in Inner Mongolia. This would be the world's largest installation and cover 25 miles of the Ordos Desert. Upon completion in 2019, the field would generate electricity to power roughly 3 million Chinese homes, equivalent to two nuclear reactors or three coal-fired plants.

It was the first deal of its kind with a non-Chinese solar company, and proved that China's energy sector was open to foreign competition. Forbes commented that First Solar was a natural choice as China's partner, given its technology and proven business model.[14] The company was expected to get up-front tax subsidies from the Chinese government. The deal also surprised

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[10] Yotam Ariel, "Incentives, Falling Cost and Rising Demand in China's PV Market," Renewableenergyworld.com, http://www.renewableenergyworld.com/rea/news/article/2009/11/incentives-falling-cost-and-rising-demand-in-chinas-pv-market?cmpid=WNL-Wednesday-November18-2009, (November 18, 2009).

[11] Christian Zeppezauer and Connie Carnabuci, "A New Revolution: China Hikes Wind and Solar Power Targets," *Renewable Energy World.com,* October 9, 2009, http://www.renewableenergyworld.com/rea/news/print/article/2009/10/a-new-revolution-china-hikes-wind-and-solar-power-targets (October 14, 2009).

[12] Ibid.

[13] Ariel, op. cit.

[14] Christopher Helman, "China's Plan to Rule the Sun," *Forbes*, September 16, 2009.

industry analysts who saw China as preferring domestic producers such as Yingli, Suntech Power, and Canadian Solar. Compared to these domestic players, First Solar had experience in bringing power downstream and developing utility-scale solar projects, as it had completed similar projects in the U.S. First Solar's entrance was also evidence that the Chinese market and government were committed to PV industry growth and that longer-term FITs would likely be established.

Despite the government's enthusiasm for PV, however, competition for initial FITs were intense as the pool of incentives was limited. Vishal Shah of Barclays Capital warned that, "It may be too early to get too excited as both timing and economics of the First Solar project could prove to be disappointing." Shah thought it very unlikely that the entire 2GW of the project would get a fixed $0.15 -$0.20/kWh FIT (he expected longer-term FITs to be much lower), and felt that the company would likely face transmission access issues and political challenges during the course of the project.[15]

China was clearly one of the most promising solar markets of the future. Solar power was particularly appealing in rural China because there was no need to build transmission lines to service the millions of rural Chinese who were not connected to the grid. Robert Stone, an energy equities analyst, went so far as to suggest that, "In due course, it will be as commonplace to install solar panels on a new house as it is to install central air-conditioning."[16] Despite this growing opportunity, Erik Oldekop, managing director of Nanosolar International, was hesitant: "The Chinese government has self-interest to generate much more demand for solar electricity and production in China. They have begun to do this but it's going to three to six years before China has 2 gigawatts of annual installations or close to the installations of Germany."

Entering China

Roscheisen explained his view of the opportunity and challenges that China represented:

> China requires a huge amount of new power development and power project development. The situation is complicated, though. The government is always in the game in China and we are a bit uncertain as to how to develop a foreign product in China and gets deals done. There are not a lot of precedents for selling to state-owned utilities.

In the past, the Chinese government had required that foreign firms that wanted to do business in China work with a Chinese partner. More recently, these rules had been relaxed and foreign firms could incorporate in China on their own. However, foreign firms were limited by import/export rules, as Roscheisen explained:

> If you set up a manufacturing entity and then the Chinese market demands your product, you can't really sell into China. Either you're a foreign company and you manufacture in China to export again, or you're a Chinese company and you

[15] Vishal Shah, "Solar Energy," Barclays Capital Research, September 6, 2009, pp. 1-2.
[16] Christopher Helman, "China's Plan to Rule the Sun," *Forbes*, September 16, 2009.

> sell in China. There have been very few hybrid structures. We want to locate in and sell in China. That's actually a fairly rare case.

Oldekop felt that, to succeed, the company needed to fully understand the business model in China, connect with the right partners, and arrange a fair revenue split between the supplier of panels and the project developers. He recognized the company's and its competitors' desire to both produce in and serve the Chinese market saying, "There is a strong urge to ask for locating a module manufacturing operation assembly there. It would also, from a business perspective, make a lot of sense to do this since the modules are heavy to ship."

Leadership at Nanosolar recognized that, in order to gain government support for solar power, a company needed, at a minimum, to manufacture solar panels in China. They were open to a panel assembly plant in China, because the company's most valuable intellectual property was not visible in this end product. But they were reluctant to open new solar cell factories there. As Oldekop explained, "There's secret sauce in our solar cells. There is a lot of intellectual property (IP) and we need protection for this IP. I don't really see the upside of having multiple solar cell factories."

Looking Forward

Oldekop and Roscheisen saw three possibilities for a China market entry. The first was to find a local partner and start a joint venture. The two parties would manufacture panels via the local partner and deliver these to the Chinese market. The success of this kind of partnership would depend on how fast the venture could achieve scale, and Nanosolar's partner selection skill.

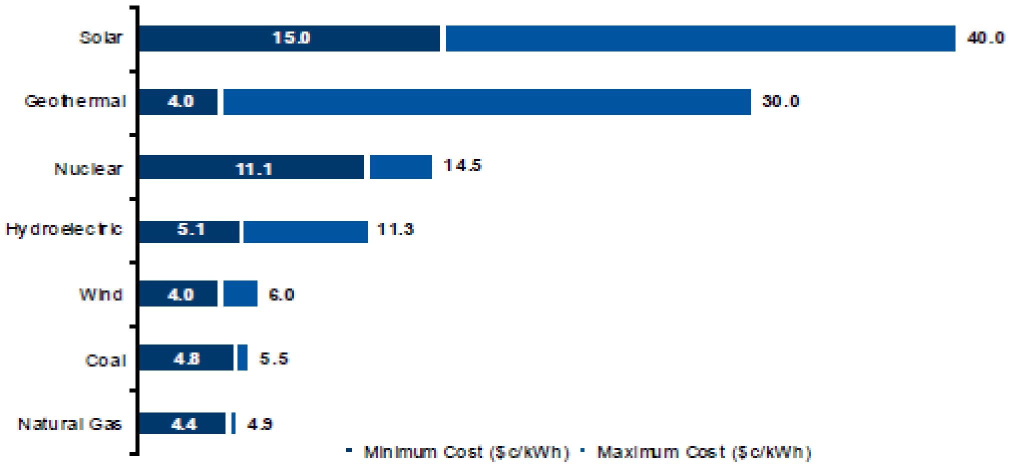
The second option would be to ship finished panels to China. The company would not have a local presence but would be able to sell products to a large and growing market. However, the panels, assembled offshore, could be stigmatized for not being Chinese panels. It was not clear if every electricity strategy in China needed to accommodate some aspect of "made in China." The amount of foreign-built modules was very small at the time. Shipping finished panels would also increase the cost of the product significantly.

Lastly, Nanosolar could negotiate with the Chinese government to establish a manufacturing presence in China, specifically the area that was most amenable to solar project development, and also establish a relationship with Chinese utilities. In order to gain visibility with the Chinese government, Oldekop believed company position was critical:

> For any new start-up, focus is the most important thing. Going to China is so attractive because of the sheer market potential. But to succeed, you need to already be a very strong player internationally. If you aren't in a position where you're producing hundreds of megawatts a year and have a strong market capitalization, it's going to be difficult to really execute on something meaningful with the Chinese government.

Roscheisen commented that the company was "inundated with requests from Chinese businessmen to visit the company." These included multi-billion dollar LCD companies, since they also concentrated in thin-film technologies. Opportunities were at the ready but the next step was not clear.

Exhibit 1
Cost of Various Sources of Energy in 2009



Source: Barclays Capital Research, *Solar Energy Handbook* 2009.

Exhibit 2
Solar Energy Glossary

Balance of System — Represents all components and costs other than the photovoltaic modules/array. It includes design costs, land, site preparation, system installation, support structures, power conditioning, operation and maintenance costs, indirect storage, and related costs.

Cadmium Telluride (CdTe) — A polycrystalline thin-film photovoltaic material

Copper Indium Diselenide (CuInSe2, or CIS) — A polycrystalline thin-film photovoltaic material (sometimes incorporating gallium (CIGS) and/or sulfur).

Crystalline Silicon — A type of photovoltaic cell made from a slice of single-crystal silicon or polycrystalline silicon.

Gigawatt (GW): A unit of power equal to 1 billion watts, 1 million kilowatts, or 1,000 megawatts. For reference, California's annual energy consumption was approximately 265,000 GW annually in 2009.

Kilowatt (kW) — A standard unit of electrical power equal to 1000 watts, or to the energy consumption at a rate of 1000 joules per second.

Megawatt (MW) — 1,000 kilowatts, or 1 million watts; standard measure of electric power plant generating capacity.

Multicrystalline — A semiconductor (photovoltaic) material composed of variously oriented, small, individual crystals. Multicrystalline was referred to as polycrystalline or semicrystalline.

Photovoltaic-Thermal (PV/T) System — A photovoltaic system that, in addition to converting sunlight into electricity, collects the residual heat energy and delivers both heat and electricity in usable form. Also called a total energy system.

Polycrystalline Silicon — A material used to make photovoltaic cells, which consist of many crystals unlike single-crystal silicon.

Photovoltaic (PV) Cell — The smallest semiconductor element within a PV module to perform the immediate conversion of light into electrical energy (direct current voltage and current). Also known as a solar cell.

Solar Systems: Solar installation has three main systems costs: solar panels, balance of system, and installation labor. The solar panels are solar cells encapsulated in glass. This power-generation subsystem converts sunlight to direct-current (DC) electricity. As electricity networks use alternating current (AC), cabling is required in order to get enough solar panels together to produce sufficient power and invert the DC power to AC power. This subsystem is called the "balance of system" or BOS.

Watt — A unit of power or rate of energy transfer equivalent to 1 ampere under an electrical pressure of 1 volt.
1 watt equals 1/746 horsepower, or 1 joule per second. It is the product of voltage and current (amperage).

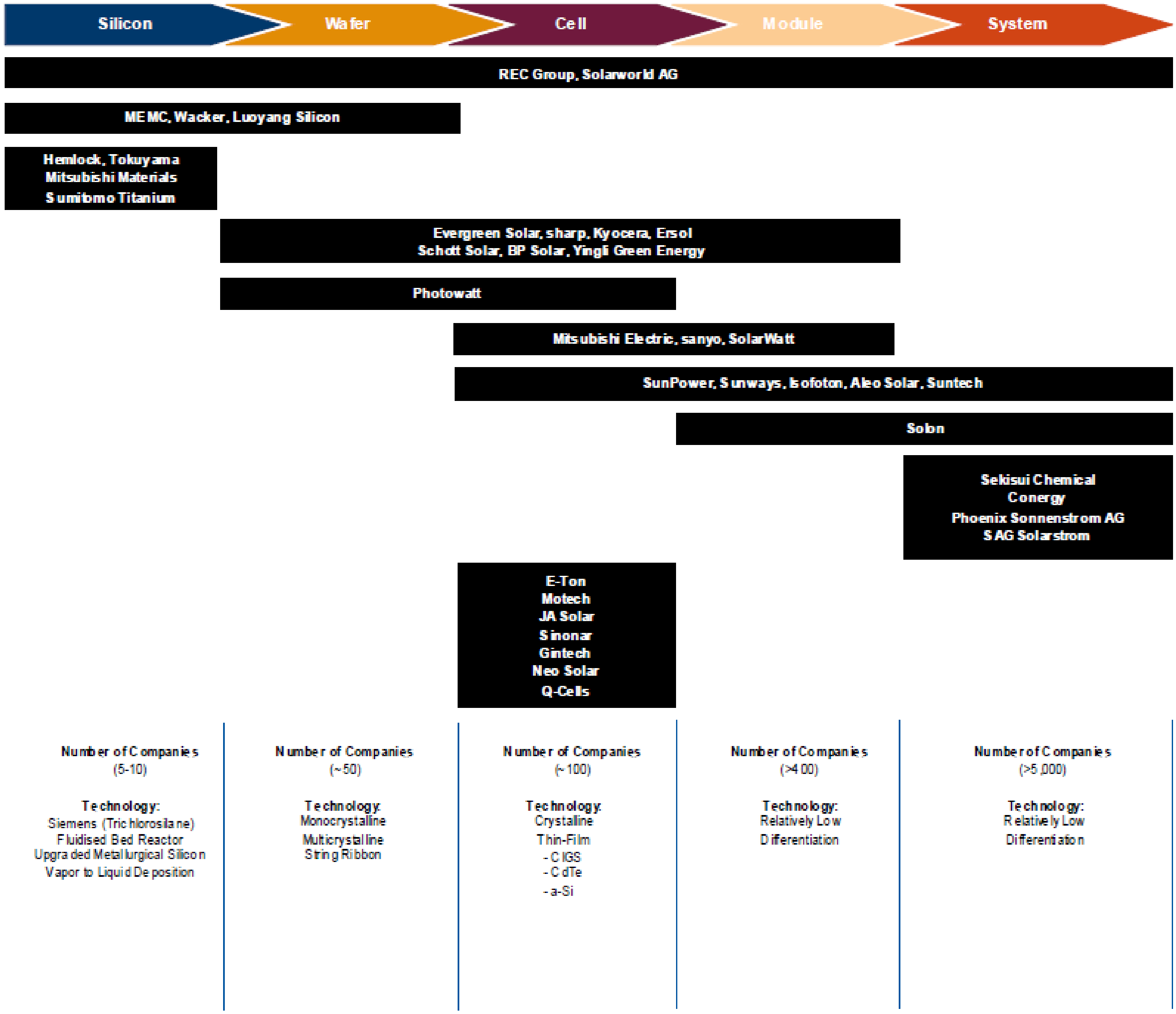
Source: Compiled by the author using http://www1.eere.energy.gov/solar/solar_glossary.html.

Exhibit 3
Solar Power Country Demand Model

MW	2007	2008	2009E	2010E	2011E	2012E
Japan	230	230	276	373	484	557
y/y (%)	-21%	0%	20%	35%	30%	15%
Germany	1,328	1,860	2,604	2,864	3,437	4,125
y/y (%)	38%	40%	40%	10%	20%	20%
Italy	87	338	507	710	1,065	1,384
y/y (%)	45%	289%	50%	40%	50%	30%
Spain	428	2,460	300	550	660	792
y/y (%)	45%	475%	-88%	83%	20%	20%
France	16	33	98	392	510	1,020
y/y (%)	50%	106%	197%	300%	30%	100%
Greece	12	30	44	87	113	147
y/y (%)	900%	150%	47%	98%	30%	30%
Czech Republi	4	7	112	146	189	246
y/y (%)	n/m	75%	1500%	30%	29%	30%
Austria	3	6	13	16	21	27
y/y (%)	56%	100%	117%	23%	31%	29%
Portugal	12	18	27	35	46	59
y/y (%)	n/m	50%	50%	30%	31%	28%
Switzerland	3	6	7	9	12	15
y/y (%)	15%	100%	17%	29%	33%	25%
The Netherlar	1	2	10	13	17	22
y/y (%)	-33%	100%	400%	30%	31%	29%
Belgium	2	4	104	135	176	228
y/y (%)	100%	100%	2500%	30%	30%	30%
Cyprus	1	2	6	9	14	20
y/y (%)	n/m	100%	200%	50%	56%	43%
Rest of Europ	107	107	46	55	66	79
y/y (%)	45%	0%	-57%	20%	20%	20%
USA	220	360	360	750	2,052	3,488
y/y (%)	57%	64%	0%	108%	174%	70%
Canada	4	9	53	370	554	832
y/y (%)	16%	125%	489%	598%	50%	50%
China	24	29	115	461	876	1,226
y/y (%)	20%	21%	297%	301%	90%	40%
South Korea	42	280	98	132	165	207
y/y (%)	100%	567%	-65%	35%	25%	25%
India	17	31	63	119	226	384
y/y (%)	45%	82%	103%	89%	90%	70%
Australia	16	20	26	36	47	57
y/y (%)	65%	25%	30%	38%	31%	21%
Israel	0	0	9	14	21	32
y/y (%)	0%	0%	2000%	56%	50%	52%
Others	164	121	75	98	127	165
y/y (%)	0%	-26%	-38%	31%	30%	30%
Total	2,721	5,953	4,953	7,374	10,878	15,112
y/y (%)	48%	119%	-17%	49%	48%	39%

Source: Barclays Capital Research, October 5, 2009.

Exhibit 4
PV Supply Chain and Major Players in 2009



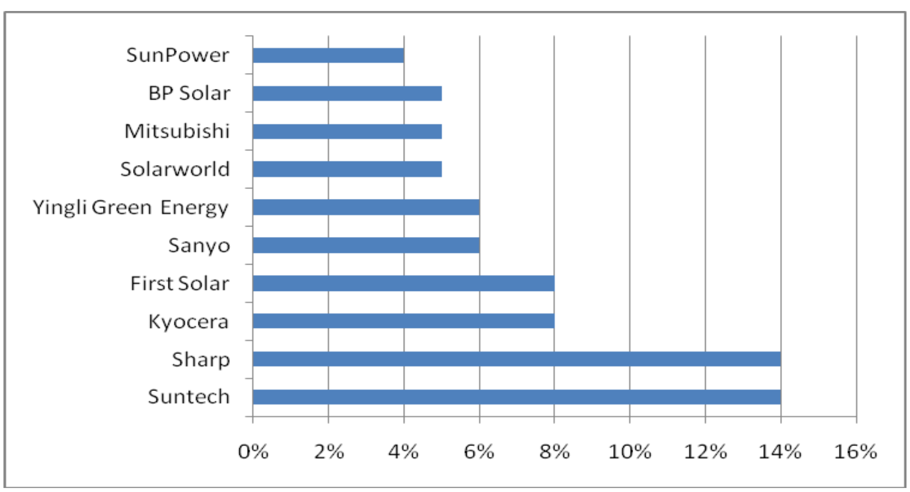
Source: Barclays Capital Research, Solar Energy Handbook 2009.

Exhibit 5
Key Solar Cell Developers and Market *Share in 2008

Company	Market Share	Technology	Country of Origin
Q-cells	7.4%	Polycrystalline silicon	Germany
First Solar	6.4%	Thin-film (cadmium telluride)	U.S.
Suntech Power	6.3%	Monocrystalline silicon	China
Sharp	6.0%	Polycrystalline silicon	Japan
JA Solar	3.8%	Monocrystalline	China
Kyocera	3.7%	Polycrystalline silicon	Japan
Yingli	3.6%	Polycrystalline silicon	China
Motech	3.4%	Polycrystalline silicon	Taiwan
SunPower	3.0	Monocrystalline silicon	USA
Sanyo	2.7%	Monocrystalline silicon (c-Si) and amorphous silicon (a-Si	Japan
Others	53.8%		

Source: Compiled by author using Photon International data (Cell Production Survey, 2008).
* Worldwide market demand was 5.9GW, and supply was 7.9GW.

Exhibit 6: Key Solar Module Developers and Market Share in 2007

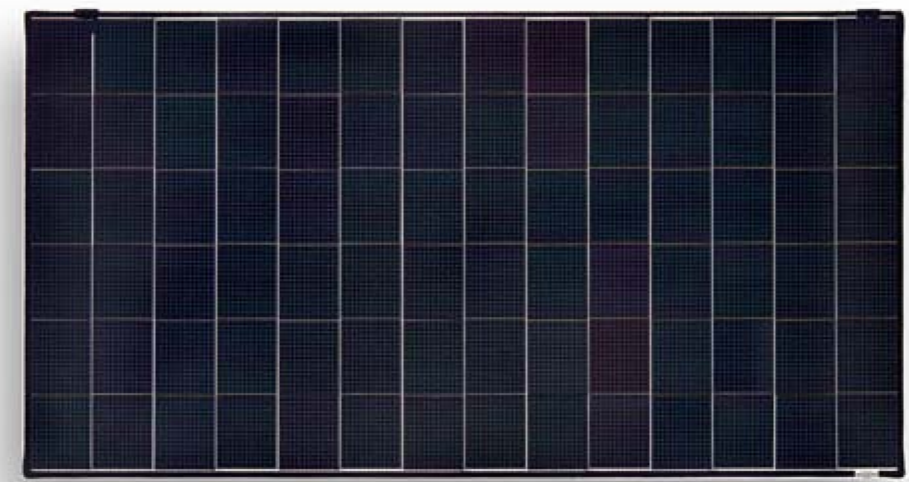


Source: Compiled by author using Barclays Capital Research data.

Exhibit 7
The Nanosolar Utility Panel

Nanosolar Utility Panel™

The Nanosolar Utility Panel™ is the industry's first solar power panel specifically designed for utility-scale deployment. Its unique features and benefits include:



A Thin Panel of 160-220 Watts	High power per panel.	Reduces installation cost.
High-Current Design	Enables longer panel arrays.	Reduces cabling and labor.
High-System Voltage	Industry-first 1500V certification.	More efficient inverter utilization.
Proven Thin-Panel Package	Rugged high-strength glass/glass laminate with edge seal.	Ensures maximum durability.
Wide-Span Mountable	Enabled by dual-high-strength glass.	Reduces mounting cost.
Nanosolar Edge Connector™	Simplifies electrical connection at utility scale.	Reduces labor cost.
Dense Pallet and Container Packing	Optimized for multi-MW deployment logistics.	Reduces shipping cost.

Engineered for >25-year reliability, the Nanosolar Utility Panel™ has met stringent suites of reliability tests. These include all applicable international standards as well as internal material, component, and panel tests substantially exceeding these standards.

Source: Nanosolar

Exhibit 8
Comparison of Nanosolar Utility Panel and First Solar Thin-Film Panels in 2009

	Nanosolar	First Solar	Nanosolar Advantage
Power (W)	160-220	75	3x Power per Layup Step
Mounting Span (m)	2	1.2	41% Less Mounting Material
Current (A)	6	1	Longer Panel Arrays
System Voltage (V)	1500	1000	Longer Panel Arrays
Panel Array Length (m)	64	12	73% Less Cabling, Labor
Connectors	Edge	Standard	85% Faster Connection
Ship per 20 ft Container (kW)	132	40	3x Lower Shipping Cost

Source: Nanosolar White Paper, "The Nanosolar Utility Panel," September 2009.

Exhibit 9
Nanosolar Strategic Partners in 2009

Strategic Partner	Primary Region
Beck Energy, Belectric: a leader in thin-film-based solar power plant development, design & construction with an annual capacity of more than 150MWp, a track record of more than 8 years and around 2,000 photovoltaic projects together with their affiliates Blitzstrom and S&F.	EU, USA, Canada
EDF EN, enXco: the renewables arm of EDF, the world's largest utility, EDF EN is a major player in the world market for green power generation, having deployed more than 1.5GW in green power.	EU, USA, Canada
AES Solar: a joint venture between the AES Corporation (NYSE: AES) and Riverstone Holdings LLC, with committed capital of $1 billion, AES Solar Energy is a leading global developer, owner and operator of utility-scale solar power plants.	EU
JuWi: one of the leading companies in renewable power plant development, with an annual turnover of more than 500M Euro and more than 1,000 photovoltaic system installations.	EU, USA, Canada

Source: Nanosolar

Appendix
A Brief Overview of PV Technology in 2009

The basis of solar cells has three parts: the semiconductor, the semiconductor junction and the contacts. The semiconductor absorbs light and converts it into electron-hole pairs. The junction then separates the electrons and holes (photo-generated carriers). The contacts on the front and back of the cell allow the current to flow to the external circuit. Solar technology differs based on the material used for the semiconductor. The technology can be either crystalline silicon in a wafer or thin films of other materials.

Crystalline Silicon Solar Cells

The dominant solar technology in 2009 (90+ percent market share) was crystalline silicon (CSI). It was the light-absorbing semiconductor in most solar cells, despite the fact it was a relatively poor absorber of light and required a considerable thickness of material. CSI panels had been in the market for over 20 years and were a very well-known technology. Within crystalline silicon, there were two main classes of cells: monocrystalline silicon and polycrystalline silicon. The most efficient product cells used monocrystalline c-Si with buried grid contacts for maximum light absorption. Much of the work involved in manufacturing these cells was menial and could be completed by low-skilled labor. Standard, polycrystalline silicon panels were the next most efficient panels.

Thin-Film Solar Cells

Thin-film solar cells made up the remainder of the solar cell market. Their appeal was that they were cheaper than crystalline silicon wafers (which accounted for 40-50 percent of the cost of a finished panel). Thin-film materials were strong light absorbers but only needed to be about 1micron thick, significantly reducing the cost of the cell. The most common thin-film materials were amorphous silicon (a-Si), cadmium telluride (CdTe) and copper indium (gallium) diselenide (CIS or CIGS). CIGS and CdTe were both polycrystalline materials.

Amorphous silicon was the most developed of all thin-film technologies. It was still silicon but in a different form. Companies producing amorphous silicon included United Solar Ovonic, (which is also referred to as ECD, Energy Conversion Devices). Amorphous silicon made the least efficient kind of solar cells—only 5-6 percent of the sunlight hitting amorphous silicon panels was converted into electricity.

Source: Nanosolar, Solarbuzz.