SunPower: Focused on the Future of Solar Power

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It was December 2006. Tom Werner, CEO of SunPower, glanced down at his watch and shook his head in dismay. His run was not going well, despite the sounds of John Lee Hooker's "Boogie Chillen" coming through his earphones. He blamed the board meeting later that afternoon.

Given SunPower's position as the producer of the world's most efficient solar cells, also known as photovoltaics or PV, and recent forecasts that solar power might be on the edge of explosive growth, he knew that he'd be asked some tough questions. Werner wondered how fast the solar power industry was likely to grow and how long SunPower's advantage was likely to last. How could SunPower compete with much larger companies like Sharp and Q-Cells? Or with the niche "technology play" firms that were springing up? How could SunPower's current advantage be turned into an enduring competitive edge?

As the sun began to rise, Werner picked up the pace again, and began jogging home.

Environmental Issues

One of the most important drivers of the world's renewed interest in solar power was its ability to offer energy independence in combination with significant environmental benefits. After all, the earth received more energy from the sun than humans consumed throughout an entire year. Since the burning of fossil fuels generated a number of noxious substances including SO_2, NO, NO_2, and particulates, concerns for human and environmental health had driven interest in solar power from its earliest days. But evidence that rising concentrations of CO_2 in the earth's atmosphere could pose large long-term environmental risks had significantly increased interest in the technology.

For over a century, scientists had observed the "greenhouse effect," the warming of the earth caused by the atmosphere's increased absorption of infrared radiation resulting from increased concentrations of CO_2 and other greenhouse gases in the atmosphere.

Levels of CO_2 had risen from around 280 parts per million volume (ppmv) before the industrial revolution to 380ppmv in 2006 higher than at any point in more than half a million years. Data presented in the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report, a 6-year study on global warming involving 2,500 leading scientists from 100 countries, provided even more alarming statistics. For example:

- Greenhouse gases rose 70% between 1970 and 2004 (28.7 to 49 billion tones per year in carbon dioxide).
- CO2, which accounted for more than 75% of emissions, increased by 80% between 1970 and 2004.
- Developed countries while accounting for 20% of the global population, contributed 46% of global greenhouse gas emissions.
- Greenhouse gases were projected to increase between 20% and 90% by 2030 unless significant changes in global energy policies were made.

Looking longer-term, many studies suggested that increasing concentrations of green house gases greatly increased the odds of catastrophic climate change. One study published in the journal *Nature* predicted that temperature increases of 3.24–3.6°F and CO^2 increases to 500–550 ppmv would result in the extinction of 1,000,000 terrestrial species (25% of all land animals and plants) by 2050.[1] Meanwhile, average global temperatures had already risen 1.33°F since 1906—and polar temperatures were rising faster still.

Most scientists believed that the stabilization of CO_2 levels was urgently required, but just what concentration constituted a "sustainable" CO_2 level was a matter of some uncertainty. The IPCC report suggested three scenarios (**Table A**) for emission stabilization by 2030 and the impact such cuts would have on global warming and world GDP growth.

Table A   *Stabilization Scenarios*

	Emission Output	Rise in Global Warming	Cost to Annual GDP Growth in 2030
Scenario A	445-535 parts per million (ppm)	3.6 - 5.0°F	0.12%
Scenario B	535-590 ppm	5.0 - 5.8°F	0.1%
Scenario C	590-710 ppm	5.8 - 7.2°F	0.06%

3[1] Marinez Ferreira de Siqueira, Alan Grainger, et al., "Extinction Risk from Climate Change," *Nature*, January 8, 2004, 427, p. 145-148.

Scenario A, involving the most aggressive action, would result in a 3% cumulative cost to annual world GDP growth by 2030. At 2006 growth rates, however, global concentrations would reach 800 ppmv by the end of the 21st century.

A sense of urgency about global warming had prompted many countries to search for aggressive, coordinated strategies to reduce CO_2 emissions. (**Table B** gives CO2 emissions for electricity production by fuel type.) The most far-reaching attempt, the Kyoto Protocol, committed a number of countries to modest CO_2 reductions by a 2012 deadline. As part of this "emission cap" approach, some signatories allocated CO_2 emissions allowances to individual firms. The Kyoto Protocol permitted these allowances to be traded across borders, creating a "carbon market." For example, a Spanish factory might find it profitable to reduce its emissions by a given amount and sell the allowances to another factory in Italy that planned to exceed its own quota. Even signatories that had not committed to emissions cuts could participate. These countries—mainly large developing countries such as China and India—could forgo emissions and sell them as credits to customers in other countries.

Table B   *CO_2 Emissions for Electricity Production*

Generation Type	Tons CO_2 per MWh
Nuclear	0
Hydro power	0
Coal	0.999
Oil	0.942
Gas	0.439
Geothermal, Solar, Tide, Wave, Ocean, Wind, Waste and other	0

Source: CANMET Energy Technologie Centre[2]

The advent of carbon trading in Europe had generated a large market. In the first half of 2006, over US$15 billion worth of carbon emissions were traded, five times more than the amount the year before,[3] and CO_2 trading schemes in the United States were being developed at the state level. As of 2006, renewable sources provided 13% of the world's energy needs,[4] while photovoltaic systems provided a mere .04% of the world's electricity. The U.S. Department of Energy estimated that the country could supply its entire energy needs by covering .5% of its land area with solar cells.[5]

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[2] Cited in B. Gaiddon, M. Jedliczka, *Environmental Benefits of PV Systems in OECD Cities*, September 2006.
[3] *Economist*, "Selling Hot Air", September 7, 2006.
[4] "Sunlit Uplands," *The Economist*, June 2, 2007.
[5] "Sunlit Uplands," *The Economist*, June 2, 2007.

Solar Power Industry

Solar cell, or photovoltaic (PV) systems converted energy from the sun into electric current. Solar cell performance was measured in terms of *conversion efficiency*, the proportion of solar energy converted to electricity. The first commercial solar cells were introduced in the 1950s by Bell Labs, and had efficiencies below 4%.[6] In 2006, PV efficiencies ranged from 10%-20% and some scientists believed that further research, combined with advances in installation methods, could push conversion efficiencies well over 20%, with 50% seen as the long-term "holy grail."[7]

A typical solar cell produced about 0.5V — roughly one-third of a regular AA battery, far too small to be of any practical use by itself — and cells were thus combined in larger blocks, called modules. Although modules varied in size, they typically included 72 cells, and yielded between 30-45V. Once constructed, modules were typically combined in arrays or panels which were then integrated with "inverters" – sophisticated devices that converted the DC power output of the solar panels or arrays into the AC power used in conventional electrical appliances.

While solar power was two to three times as expensive as the retail cost of electricity,[8] the market continued to grow at a steep upward trajectory. As **Figure 1** shows, module manufacturing began to ramp up a few years after module prices hit a plateau. (**Exhibit 1** provides yearly production and price data spanning 1975 to 2005.) Solar photovoltaic power grew an average of 41% each year between 2003 and 2006,[9] and was expected to grow 40% annually through 2011. Industry profits were expected to top $7.7 billion in 2007 and $11.5 billion by 2011.[10] Roughly $1.7 billion in private equity and venture capital funds went into the industry in 2006 and another $4.5 billion was invested in publicly traded solar companies, most of it going toward expanding manufacturing capacity.[11]

[6] http://www.nrel.gov/learning/re_photovoltaics.html
[7] Vaclav Smil, 2003. *Energy at the Crossroads*, Cambridge: MIT Press, p. 288.
[8] "Bright Prospects," *The Economist*, March 8, 2007.
[9] "Sunlit Uplands," *The Economist*, June 2, 2007.
[10] Liz Skinner, "Sun Will Shine on Solar-Energy Investing, Report Says," *Investment News*, June 18, 2007.
[11] Cassidy Flanagan, "New Light on Solar Energy," *Business Week*, May 17, 2007.
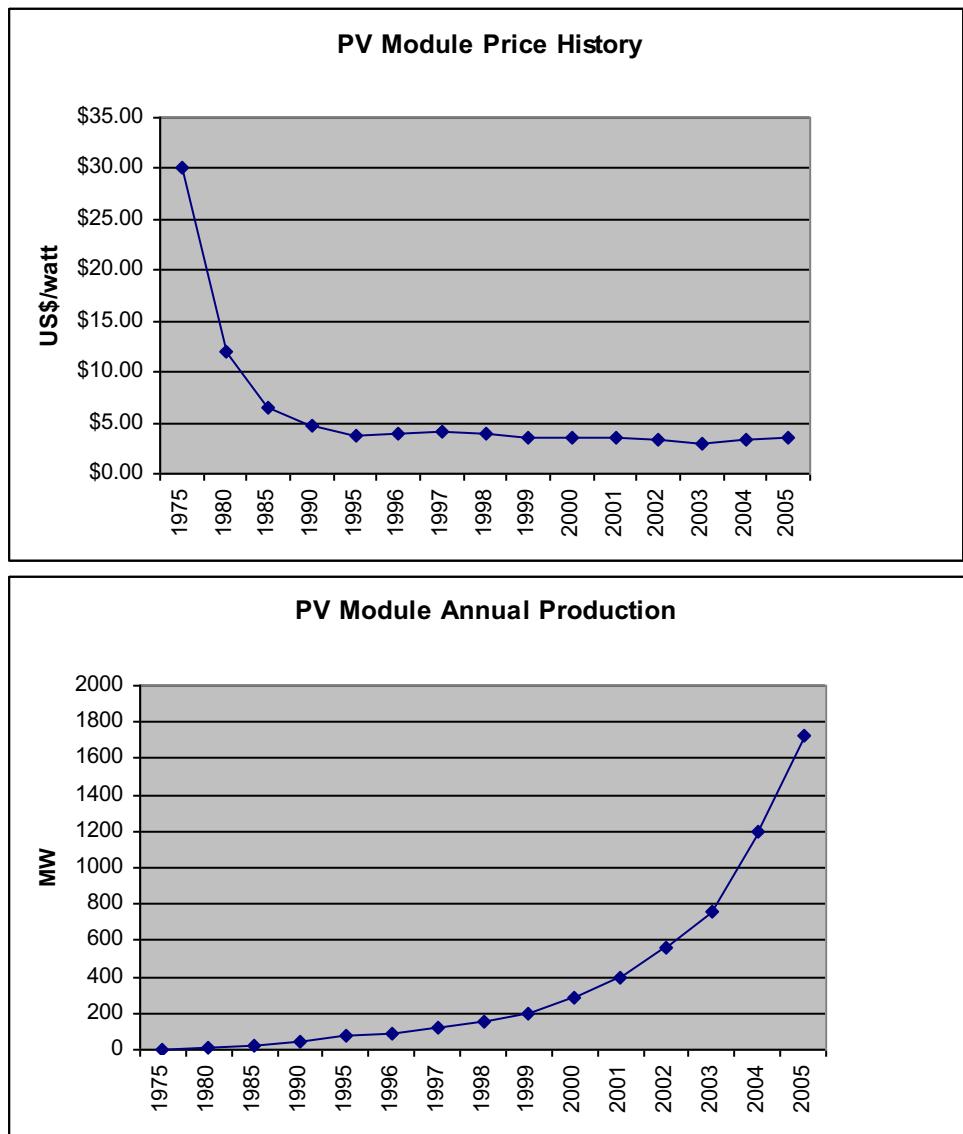
Figure 1   ***PV Module Price and Production History, 1975-2005***

**PV Module Price History**

PV Module Annual Production
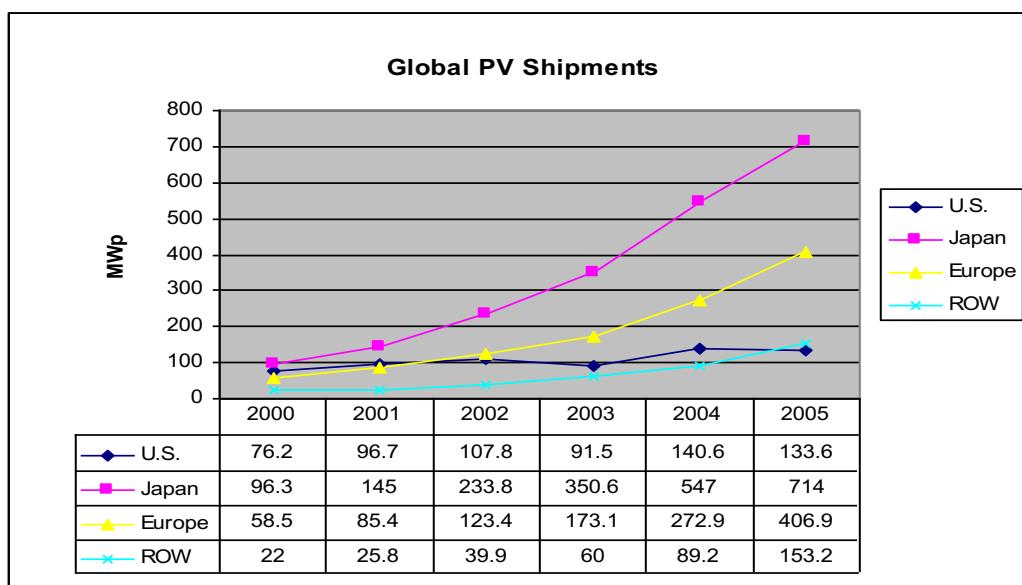
Source: Maycock.

Producers and Consumers

Japan was the world's PV shipment leader, shipping more than five times the volume of the United States (**Figure 2**). Since 2002, Europe had held the number two position after it passed the United States and by 2005, Europe was shipping three times the volume of the United States. Analysts blamed the erosion of U.S. PV market share to a lack of manufacturing incentives and high manufacturing costs.

Figure 2   *Global PV Shipments, 2000-2005*

Global PV Shipments

	U.S.	Japan	Europe	ROW
2000	76.2	96.3	58.5	22
2001	96.7	145	85.4	25.8
2002	107.8	233.8	123.4	39.9
2003	91.5	350.6	173.1	60
2004	140.6	547	272.9	89.2
2005	133.6	714	406.9	153.2

Source: Paula Mints, "PV in the U.S.: Where is the market going and how will it get there?", Renewable Energy Watch, September 2006.
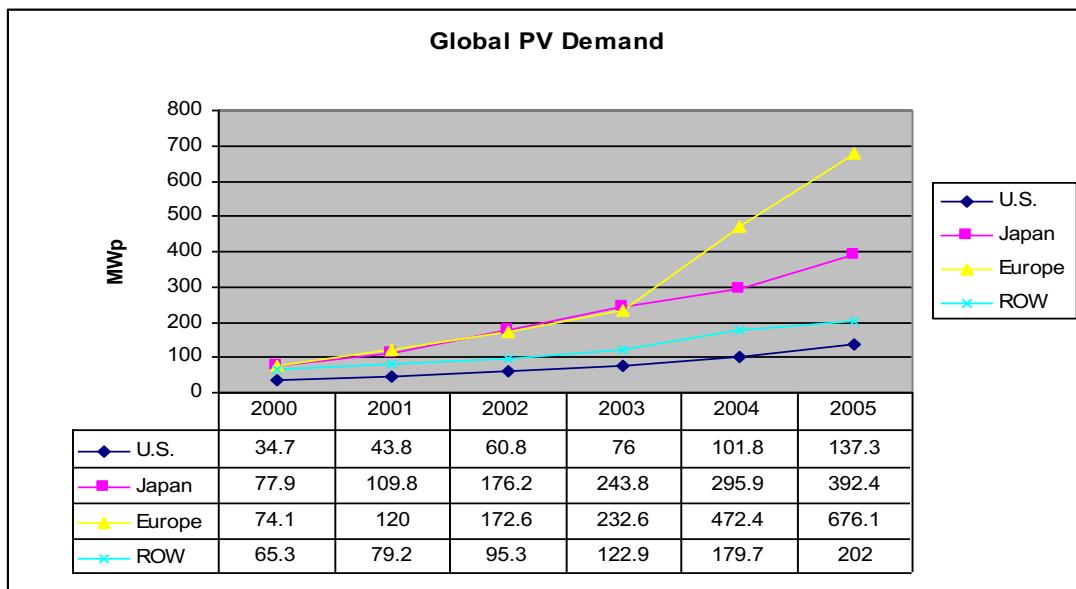
Analysts' expectations that China was the market to watch due to its growing energy needs, large work force and strong industrial base were proven correct in 2006 when China surpassed the United States as the world's third largest producer of PV cells, behind Germany and Japan. Lacking any kind of domestic incentive/subsidy policy, more than 90% of China's PV products were exported. Chinese PV producers raised billions of dollars in international IPOs in 2005 and 2006 to build capacity and increase scale with the goal of driving down costs.[12]

On the consumer side, global PV demand had grown from 114 MWp in 1997 to 505 MWp in 2002 to 1,408MWp in 2005 and 2,500MWp in 2006 and demand was accelerating rapidly particularly in Europe (most especially Germany) and Japan as shown in **Figure 3**. One prominent analysis of

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[12] Gail Roberts, "Production Trends and New Technologies Could Push Solar Energy into Mainstream," *Electric Utility Weekly*, May 28, 2007.

potential demand at 2006module prices—i.e., around \$3.50-\$4.50/W with policy support—estimated that there was potential worldwide demand of approximately 5,000MWp, or double 2006 industry sales. Meanwhile, global grid-connected solar capacity was about 5,000MWp. In contrast, installed wind capacity in the United States alone was 9,149MWp.[13]

Figure 3   Global PV Demand, 2000-2005

Global PV Demand

	2000	2001	2002	2003	2004	2005
U.S.	34.7	43.8	60.8	76	101.8	137.3
Japan	77.9	109.8	176.2	243.8	295.9	392.4
Europe	74.1	120	172.6	232.6	472.4	676.1
ROW	65.3	79.2	95.3	122.9	179.7	202

Source: Paula Mints, "PV in the U.S.: Where is the market going and how will it get there?", Renewable Energy Watch, September 2006.

The Solar Value Chain

There were five key stages in solar power's value chain: silicon production, ingot/wafer manufacture, solar cell manufacture, solar module manufacture, and system installation. Firms in the industry differed dramatically in the degree to which they participated in each stage. (**Table C** shows revenues and profits across the chain.)

Table C   PV Industry Value Chain Snapshot

Year: 2006	Silicon	Ingots/Wafers	Cells	Modules	Installation
# of players	20	40	100	500	5,000
Revenues ($m)	1,400	4,500	7,700	10,200	3,200
Pre-tax margin (%)	53	36	21	5	20
Capital costs ($/w/year)		0.65	0.50	0.05	

Source: Solar Annual 2006

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[13] Gail Roberts, "Production Trends and New Technologies Could Push Solar Energy into Mainstream," *Electric Utility Week*, May 28, 2007.

Silicon The key feedstock in the PV industry was high-purity silicon, which was the basis for more than 90% of solar modules. Silicon was obtained from sand through a complex process using numerous purification steps and temperatures up to 1,100ºC which would turn sand into the high purity silicon known as polysilicon.[14]

As recently as the early 2000s, solar cell producers sourced silicon feedstock mainly from waste silicon discarded during semiconductor manufacturing. This "leftover" silicon supply included high-purity silicon that was slightly above or below the quality specified for semiconductor production, or off-cuts (tops or tails) of monocrystalline ingots. For their part, silicon producers had historically considered solar cell makers a market of last resort, useful for stabilizing fluctuations in the overall semiconductor market but unlikely to amount to meaningful scale.

The explosive growth of PV cell manufacturing, however, had transformed the role of solar power in the silicon business. In 2005, the solar industry used approximately 47% of available silicon, and in 2006 it would likely account for the majority share. These fast growing needs had stretched global silicon supply and prices had risen dramatically from $32/kilogram in 2004 under a long-term contract, to $45/kg in 2005, to a predicted $55/kg in 2006 with short-term contracts exceeding $200/kg. However, current investment plans would triple capacity, from 31,000 tons per year in 2005 to 100,000 tons or more by 2010,[15] despite the fact that a 5,000 tons/year expansion cost roughly $300 million. The silicon shortage was expected to end around 2008 when supply was estimated to grow 70%.[16]

Ingots / Wafers Many large solar cell manufacturers had in-house ingot production and wafer sawing capabilities, including REC, SolarWorld, Kyocera, and BP Solar. Dedicated ingot and wafer manufacturers supplied wafers to the solar cell manufacturers that did not have their own ingot and wafer capabilities. Technical progress in the industry had been rapid. In 2004 typical wafers were 250-300 microns thick, and by 2006 they were around 190 microns. However over the same period prices had risen dramatically. In 2004 wafers were sold for around $1.00/watt, while in 2005 the average price was $1.25/watt and in 2006 it was expected to be $1.90/watt.

Cells and Modules Solar cell manufacturing was a widely understood process that involved less than ten steps. The largest producers, which included Sharp Solar (Japan), Q-Cells (Germany), Kyocera (Japan), Sanyo (Japan), and Mitsubishi Electric (Japan), together accounted for roughly 58% of the market. Sharp was the clear market leader, with 427.5 MW of production in 2005, nearly three times that of its nearest competitor. Between 50 and 100 manufacturers made up the rest of the industry's production capacity.

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[14] Million Roofs handout
[15] *Policysilicon: Supply, Demand, & Implications for the PV Industry*, Prometheus Institute, 2006.
[16] Brian Womack, "Alternative Energy Sun Shines on Clean Energy," *Investor's Business Daily*, May 21, 2007.

Due to the global silicon shortage, solar cell prices rose from $2.70/watt in 2004 to $2.50/watt in 2005, and were forecast by Photon Consulting to rise to $3.25/watt in 2006. At expected 2006 prices, pre-tax cell manufacturing profit margins were expected by Photon Consulting to be 21%. While there were roughly 500 smaller module manufacturers in operation in 2006, most of the top cell manufacturers made modules as well. In parallel with increases in PV cell prices, average module prices had also risen from $3.20/watt in 2004 to $3.75/watt in 2005, and were expected to reach $4.30/watt in 2006.

System Installation / Integration The most advanced systems integrators had expertise in installing megawatt-scale solar systems at low costs in fields and on large commercial roofs. Competition for these large projects was fierce, and margins were tight even for the best integrators. On the other side of the installation spectrum, small residential installers made up the majority of the 5,000+ solar installers and integrators in operation. In general costs and prices varied widely, depending on the application and geographical region. Total installation costs ranged from $1/watt to $3/watt, and consumer prices ranged from $1.25/watt to $4/watt. For dual-axis trackers in large field installations, area-related costs could reach $1.50-$2.00 per watt, while commercial flat roofs, where aesthetics were less important, were usually around $0.60 per watt. Residential roof installations cost approximately $1.00 per watt for area related costs.

While solar installation was fairly simple at a very basic level (one secured racks to the roof and then attached modules to the racks and plugged them in), there could be meaningful first mover advantage for installers that developed expertise in an end-consumer market. For example, the installer that put a system in for a Best Buy could be rewarded with lower costs selling to other 'big box' retailers because it understood both the sales process and the needs of that type of customer. Similarly an installer that developed expertise in, for example, residential installations in San Diego, could develop lower costs in residential installation in San Diego than potential entrants.
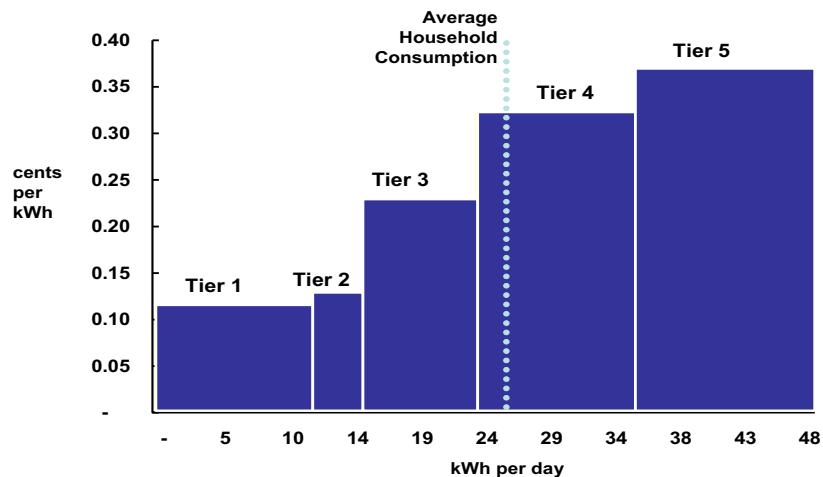
Pricing

Deriving an exact price for solar generated electricity was tricky. While conventional power was sold as a flow of power from the grid in units of $/kWhr, solar power was typically sold as an installed system with an upfront capital cost measured in units of $/peak watt. Deriving a flow cost — how much the user would actually pay for kWhrs and how much they would pay per installed watt of generating capacity — depended on a wide range of factors including the life of the system, interest rates, subsidies (if any), hours of sunshine and so on. Hours of sunshine, for example, ranged from nearly six per day in parts of Southern California to 2.5 hours per day in parts of Northern Europe, with important seasonal variation – and both interest rates and the subsidies given to solar power varied widely across the world.

In general, however, the average price of solar power ranged from US 25-50¢ per kWh. For example, as **Exhibit 2** suggests, the average cost of a residential PV system in California translated into an electricity price, without subsidies, of roughly 31¢/kWh. In contrast, one could generate electricity using conventional power sources for between 4¢/kWh and 6¢/kWh (**Exhibit 3**). Final prices to the consumer could be significantly higher because electricity was expensive to distribute, but on average conventionally generated electricity was still significantly cheaper than solar power. According to the Organization for Economic Cooperation and Development (OECD), prices for household customers started at just several cents per kWh in areas of Scandinavia and rose to over 25¢/kWh in the highest-priced markets such as Japan. The U.S. average was 9.6¢/kWh in early 2006, with California prices averaging over 13¢/kWh.

As **Exhibit 4** suggests, however, the average price of electricity told only part of the story. In markets around the world, some customers paid significantly more than the average price of electricity. In California, for example, commercial customers paid 24% more per kWh than residential customers. Meanwhile, the state further stratified prices into five tiers based on total electricity usage per month. As **Figure 4** shows, a California customer that consumed more than 34 kWh per day would pay 37¢, Tier 5 prices, for every kWh over the 34 kWh/day limit of Tier 4.

Figure 4   California Residential Power Pricing Structure, September 2006

Source: Pacific Gas and Electric.

Given its high cost, up until the late 1990s, most PV power was used to meet the demands of "off the grid" users. Since that time, however, more solar panels had been sold to residential customers than any other single segment. Panels, attached to the roof of a house or apartment building, could in many cases give households full or near self-sufficiency in power supply. In markets that permitted net metering, households also had the option to sell their excess power to the grid. Under favorable

pricing ("feed-in tariffs"), this option could dramatically improve the economics of a home PV system.

Increasingly, solar systems were also finding a market among large commercial facilities such as big box retail stores, shopping malls, hospitals, and airports. In most cases, solar cells were not substituted completely for grid-based electricity, and customers continued to purchase from the commercial grid. Some commercial customers installed PV systems as a hedge against high electricity prices while others recognized the potential public relations benefits of a "green power" investment. Utility-scale applications were once regarded as the main potential market for solar power. Until the late 1990s, for example, parabolic concentrators at three sites in California's Mojave Desert accounted for more than 90% of the world's installed solar capacity.[17] However operational and financial challenges had made this vision obsolete. The firm that built the Mojave facilities, Luz International, went out of business. Solar towers were also slow to take off and only a few experimental facilities, mostly under 1 MW, had opened in California, Spain, Israel, Germany, and Australia.[18]

Policy Support

Solar power's potential to increase energy independence and reduce carbon emissions had led to a wide variety of public subsidies. Around the world, there were more than 1,000 various pro-solar policies put in place by international, national, and local authorities. California's "Million Solar Roofs" initiative, for example, had allocated $3.2 billion for solar power "buy-downs" through 2016. (A buy-down reduced the upfront capital expenditure required to install a solar system.) In some jurisdictions, customers could sell excess solar power back to their utility at favorable prices. Some governments had set specific targets for the number of households with PV systems, or renewable portfolio standards (RPS) which required utilities to derive a targeted percentage of power from renewable sources and/or solar power. In South Korea, for example, government mandated a target of 1,300 MW of solar power installations by 2012 and in the United States, 24 states had implemented their own RPS. (See **Exhibit 5** for list of standards by state.)

The U.S. solar market was highly diverse. State regulations and policies toward solar power ranged from the supportive to the non-existent, and power prices, the availability of solar radiation, and public attitudes toward the environment also varied dramatically across states. **Exhibit 6** compares the costs and savings for a solar system installed in California, Texas and Massachusetts based on the same monthly electric usage. While a California resident's estimated net cost would be roughly $17,480, a Massachusetts resident would likely pay nearly twice that amount. Meanwhile, rebates and credits in the state of California ($18,250) equaled half of the installation price. In Texas they were 38% and in Massachusetts 23%.

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[17] Smil, p.285
[18] Ibid.

Quantifying public subsidy policies into a global total of pro-solar spending was difficult, but one analysis estimated that a total of $1.7 billion was spent by governments worldwide in 2005 in supporting solar power, and that this figure would surpass $3 billion in 2006.[19] For companies like SunPower subsidy programs were critical in generating demand. But analysts believed that the industry would be able to prop itself up without subsidies by 2012.[20] Of course the key to doing so was lowering costs and scaling up production.

SunPower

SunPower was founded in 1987 by Dr. Richard Swanson, a professor of electrical engineering at Stanford University. At the time it closed its Series A round of VC financing in 1989, SunPower's goal was to commercialize solar concentrator[21] technology. However, according to Swanson, the company ended up going in a different direction:

> We realized that solar concentrators were a bad idea. Conceivably, someday concentrator systems could be a lower-cost PV alternative, but they are not now and they have a long way to catch up with continually improving flat-plate systems. Moreover, concentrators are not well suited for many small distributed, remote applications.   We wrestled with whether we should give the money back to the VCs or not. Ultimately, we chose not to. Starting in about 1991, SunPower went through a long period of trying to find its way.

In the early 1990s, the Honda Motor Company approached SunPower asking if the company, known for its efficient solar cells, could make cells big enough to cover Honda's solar powered race car. After agreeing to Honda's request, Swanson realized there was one barrier standing in the way of SunPower's ability to deliver: "We were all from academia. We argued for about four hours one day about whether we needed two shifts or one shift and realized after a while we had no idea how to figure out whether we needed two shifts or one shift."

After hearing about SunPower's dilemma, Swanson's friend T.J. Rodgers had the answer. Rodgers, founder and CEO of Cypress Semiconductors, suggested that SunPower tap into some of his company's talent that had been recently laid off, particularly his former VP of operations. "He's kind of a drill sergeant," Rodgers warned Swanson, "but that's what you academic types need."

Within three weeks SunPower had been transformed from an R&D fab into a full-blown solar cell manufacturer operating 24-hours a day. Powered by SunPower's cells, Honda went on to win the race across Australia by more than a day over the second place car.

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[19] Simil, p. 47.
[20] Brian Womack, "Alternative Energy Sun Shines on Clean Energy," *Investor's Business Daily*, May 21, 2007.
[21] Solar concentrators use optics, such as mirrors or lenses, to focus sunlight onto the solar cells that convert light to electricity. By magnifying light, designers can generate more power from solar cells made of silicon and other expensive materials.

After the Honda experience, NASA approached SunPower to provide cells for a solar powered airplane. The plane was called Helios, and it had set a record for highest sustained level flight, at 96,500 feet. SunPower provided a 35 kW array of hand-made solar cells at $200/watt. NASA wanted to order more, but asked SunPower to try to reduce the cost.
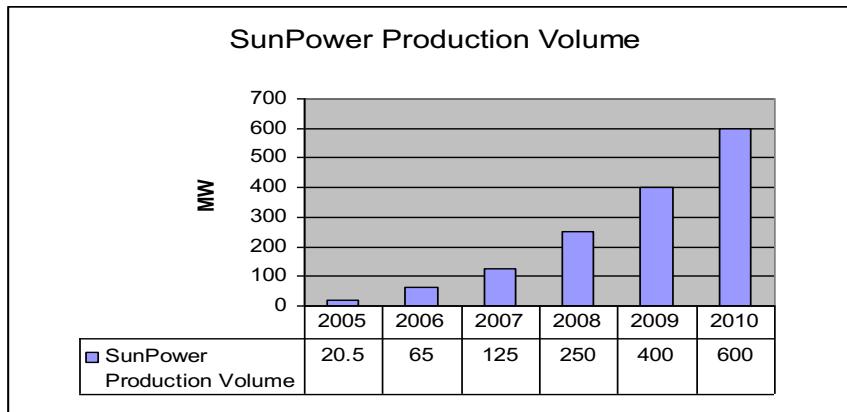
Based on NASA's request, it became obvious to Swanson that in order to survive, SunPower would have scale up its production. "We decided that the secret was to do what we know best, and that was calculating things," Swanson recalled. "We built a factory model, and tried to figure out how much it would really cost us if we made solar cells in volume. Because of the efficiency of our cells which allow us to get more watts for each process step and more watts for each gram of silicon, we believed that we could compete."

While SunPower was unable to convince many investors about its potential, T.J. Rodgers believed that Cypress and SunPower were a match made in heaven, and proposed a partnership to Swanson: "We'll marry our expertise in semiconductor manufacturing that we have honed over 25 years of world class competition, our understanding of how to run a fab, and our knowledge of how to transfer products from R&D into manufacturing with your technology. Together we'll create a great solar company."

The partnership with Cypress, which began in 2001, allowed SunPower to begin solar cell commercial production in late 2004, and in November 2005, the company went public on the NASDAQ stock exchange. Resulting from a large investment by T.J Rodgers, Cypress retained a majority stake.

Within one year, SunPower produced approximately 20 MW of solar power, and in 2006 the company expected to produce around 65 MW (**Figure 5**). Revenues rose from $6 million in 2004 to $78.8 million in 2005, and were projected to surpass $220 million in 2006. The second quarter of 2006 was the first profitable quarter in company history. (See **Exhibit 7** for financials.)

Figure 5   ***SunPower Production Volume***

SunPower Production Volume

	2005	2006	2007	2008	2009	2010
SunPower Production Volume	20.5	65	125	250	400	600

Source: SunPower, Photon Consulting

While SunPower initially focused on the production of solar cells, the firm soon integrated into the manufacture of modules, followed by a move into wafer manufacturing. In July 2006, SunPower signed an agreement with the South Korean company, DC Chemical, to support the construction of DC's first silicon production facility. In return, SunPower gained a substantial, long-term source of silicon supply, at a time when there was a shortage of silicon. In September 2006, SunPower invested in a joint venture with a Chinese company to manufacture ingots and in December 2006 it acquired PowerLight, a California-based installer that specialized in large installations over 100 kWp, for $335 million.

SunPower's Core Capability

SunPower produced the highest efficiency solar cells commercially available in 2006. By focusing early on developing cells for solar concentrator technology, SunPower was able to create a differentiated type of solar cell in which the metal contacts and grids were located on the back side of the cell. This design improved efficiency by allowing more sunlight to hit the silicon material in the cell rather than bouncing off the metal grids, and also allowed for a more uniform all black appearance which some customers found aesthetically preferable.

Higher efficiency and improved aesthetics, however, came at a cost. SunPower's manufacturing process required approximately twice as many steps as the typical solar cell manufacturing process. Meanwhile, some of these steps were unique to SunPower, raising capital expenditure per watt. The firm estimated capital expenditure per watt was around $1.00, while the cost of manufacturing a cell was roughly $2/watt. Of that cost, $1.20 was for the silicon wafer, while the remaining $0.80 covered the cost of processing the wafer into a cell. A good portion of SunPower's process development was carried out in the Philippines in order to take advantage of the increased technical capabilities and low cost of Filipino engineers. Manufacturing, meanwhile, was done in the United States.

To the extent that SunPower's processes mirrored the typical production process, the company benefited from manufacturing equipment innovations. Many industry players believed that crystalline manufacturing costs could see cost reductions of 25% by 2010. (See **Exhibit 8.**) As Werner explained:

> Generic advances move quite rapidly across the industry as they do in all industries now. We use approximately 2/3 of the same equipment vendors as our competitors. So inevitably vendors sell improvements that we give them to our competition, and vice versa. Manufacturing excellence is partially about how quickly you adapt those advances, and how aggressively you try to find out about the advances.

SunPower's high efficiency cells also gave it a competitive advantage in the systems installation segment of the value chain due to the fact that higher efficiency cells and modules packed more power production capacity into a given space. Therefore a house with limited roof space could install more solar capacity. Fewer modules and less covered area also meant less installation cost, and SunPower's customers, the installers, were reportedly willing to pay a higher price for the panels. "Our channel checks tell us that [the premium] is at least 10%," Werner stated.

SunPower had publicly committed to increasing the average efficiency of its solar cells from its 2005 level of 20.7% to at least 22% by the first quarter of 2007. Some of these efficiencies, it was hoped, would come from reducing the grams of silicon per watt from its 2005 level of 7.5 grams per watt (the industry average was approximately 10 grams per watt) and reducing wafer thickness from 190 microns to 170 microns or below. But, as Werner noted, it would not be an easy goal to achieve: "I think it's like losing weight. Those last two pounds are really tough. That could stretch out over a number of years."

Speaking about SunPower's technology advantage, Werner commented:

> The great internal debate is how long SunPower's lead is. Are we Intel where we can focus on this and drive this for 10 years or more, much like they did for decades in the microprocessor industry, or are we like many other industries where you have an advantage that is perishable in a timeframe such that you had better find a new innovation plane….

Downstream, SunPower intended to help squeeze costs out of the residential retrofit installation and integration business, which accounted for around half of the final selling price of an installed system. SunPower believed that the installation segment of the value chain was underscaled, and intended to help its installer partners scale the fixed cost aspects of their businesses. In the industry as a whole, the final assembly and installation of solar systems (the so-called "Balance of System") had seen dramatic cost reductions. Standardization via the emergence of "cookie cutter" applications, such as a 2 kW standard roof-mounted system, had brought some consistency to planning, mounting, and

materials use. Improvements in other installation costs was difficult to document, but some solar analysts believed that costs had fallen by at least the same amount as PV modules.

The Competition

SunPower's competition consisted of 15-20 established cell manufacturers, a handful of silicon-based cell manufacturing upstarts, and a number of thin film solar companies offering potentially disruptive technologies.

Sharp Solar Headquartered in Japan and with significant operations and market share in Germany and California, Sharp Solar was the industry market leader with a 26% market share—427.5 MW of cell and module production in 2005—, and 32% year-on-year growth over 2004. Its cell production processes, based on standard technology, were the result of over 40 years of research and development. Sharp operations spanned wafer, cell and module production, and it was pursuing R&D in thin films, concentrator technology, and solar integrated products. Its modules had been characterized as reliable, workhorse solar modules, "the Chevy of the solar industry."

Sharp solar modules were primarily based on multicrystalline solar cells[22] with efficiencies of 14-15%. Due to standard module efficiency losses, the modules were approximately 13% efficient. While Sharp derived the majority of its revenue from basic modules, it had also introduced a range of low volume, innovative products, including triangular modules to fit in tight corners and translucent solar window glass with integrated LED lights. Sharp had also researched back contact solar cells, similar in nature to the cells produced by SunPower.

Q-Cells Germany-based Q-Cells was the industry's second largest player by market share, producing 165.7 MW of solar cells in 2005, good for 118% year-on-year growth. As the industry's fastest growing company, Q-Cells primarily produced multicrystalline solar cells with efficiencies of 14.5%-15.5%, as well as monocrystalline cells[23] with efficiencies of 16%-17%. The company had developed large format cells (8" square instead of the standard 5" or 6" squares) in order to reduce processing cost per watt, but, as of 2006, these cells were not in large scale production.

Q-Cells had taken a portfolio approach to emerging solar technologies with minority investments in a range of potentially disruptive companies, including a joint venture Evergreen Solar and investments in a number of thin film solar companies.

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[22] Multicrystalline cells are produced using numerous grains of monocrystalline silicon. While multicrystalline cells are cheaper to produce than monocrystalline ones, due to the simpler manufacturing process, they tend to be slightly less efficient, with average efficiencies of around 12%.(http://www.flasolar.com/pv_cells_arrays.htm)

[23] These cells are made from very pure monocrystalline silicon which has a single and continuous crystal lattice structure with almost no defects or impurities. The principle advantage of monocrystalline cells are their high efficiencies, typically around 15%, although the manufacturing process required to produce monocrystalline silicon is complicated, resulting in slightly higher costs than other technologies. (http://www.flasolar.com/pv_cells_arrays.htm)

REC Group   Renewable Energy Corporation ("REC Group") was the only fully-integrated solar company, with production along the entire value chain from silicon production to module manufacturing. The company's silicon and wafer manufacturing volumes placed it among the industry leaders, while its cell and module production was still developing. REC Group was also the only major silicon manufacturer which produced silicon only for the solar industry.

REC Group began operations in Norway in 1994 as ScanWafer. Up until 2002, the company primarily produced wafers, after which time it entered a joint venture with a silicon manufacturer, and eventually bought out its JV partner to fully own the silicon plant. In 2003, REC expanded into cell and module manufacturing and in 2005 it purchased another silicon manufacturing facility, placing it solidly among the top five silicon manufacturers in the world.

REC Group produced more silicon than it used to manufacture wafers, and produced more wafers than it used in its cell and module manufacturing, putting the company in the unique position of both supplying and competing with its customers at the wafer, cell and module level. The company intended to reduce the cost of producing a solar module 50% by 2010.

First Solar   Based in Arizona, First Solar was one of the more mature thin film solar manufacturers in the industry. The company relied on a compound of Cadmium Telluride (CdTe) instead of silicon to produce its modules, and as a result its modules were 8%-10% efficient instead of the 13%-18% efficiencies found in silicon-based modules. In an IPO registration statement filed in the summer of 2006, the company reported module manufacturing COGS of $1.59/watt.

Industry watchers and competitors expressed concern over the toxicity of the cadmium contained in its modules. First Solar contended that the concerns were exaggerated, given that the amounts were so small and so unlikely to enter the environment.

SunTech   In 2005, China-based SunTech was the world's 8th largest PV producer and by the end of 2006 the company had moved into 4th place with 240 MW of photovoltaic cell capacity. Meanwhile, SunTech's production topped 160.1 MW in 2006 and was estimated to more than double in 2007 to 325 MW.[24]   While the company exported more than 90% of its products, mainly to Germany and Spain, it hoped that by 2015, 20% of its products would be sold in China. SunTech's CEO was pressing the Chinese government to start offering incentives for the photovoltaic cell industry.

Citizenre   Industry newcomer Citizenre, based in Delaware, was attempting to disrupt the industry by offering a new business model by which the company would manufacture, pay for, install, own, maintain and operate the solar PV system installation while homeowners would be required to pay for the electricity generated by the PV panels at a fixed rate for a set period of time. Many

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[24] J.R. Wu, "China SunTech Ups Output, but Prices Pressured," *Dow Jones Interantional News*, June 19, 2007.

industry veterans were skeptical about Citizenre's ability to deliver as the company did not yet have a product to sell nor had it disclosed information on those investors who had purportedly committed $650 million to the company.[25]

Conclusion

SunPower had come a long way from the days when it was making solar cells that powered Honda's solar powered race car to victory. In 2006, the company found itself competing in an industry experiencing tremendous growth and increasing public and private sector support whether in the form of subsidies or direct investment. However, in light of the varied and continually evolving competitive scenario that SunPower had become a part of, company CEO Tom Werner was aware that the road ahead would likely be a challenging one.

The key was choosing and formulating the right strategy. Should, for example, SunPower's strategy focus on the pricing of modules? Or should it focus more on investing in process improvements? Or should the strategy be some combination of the two? If so, what was the right formula based on the multitude of variables that solar cell producers like SunPower faced?

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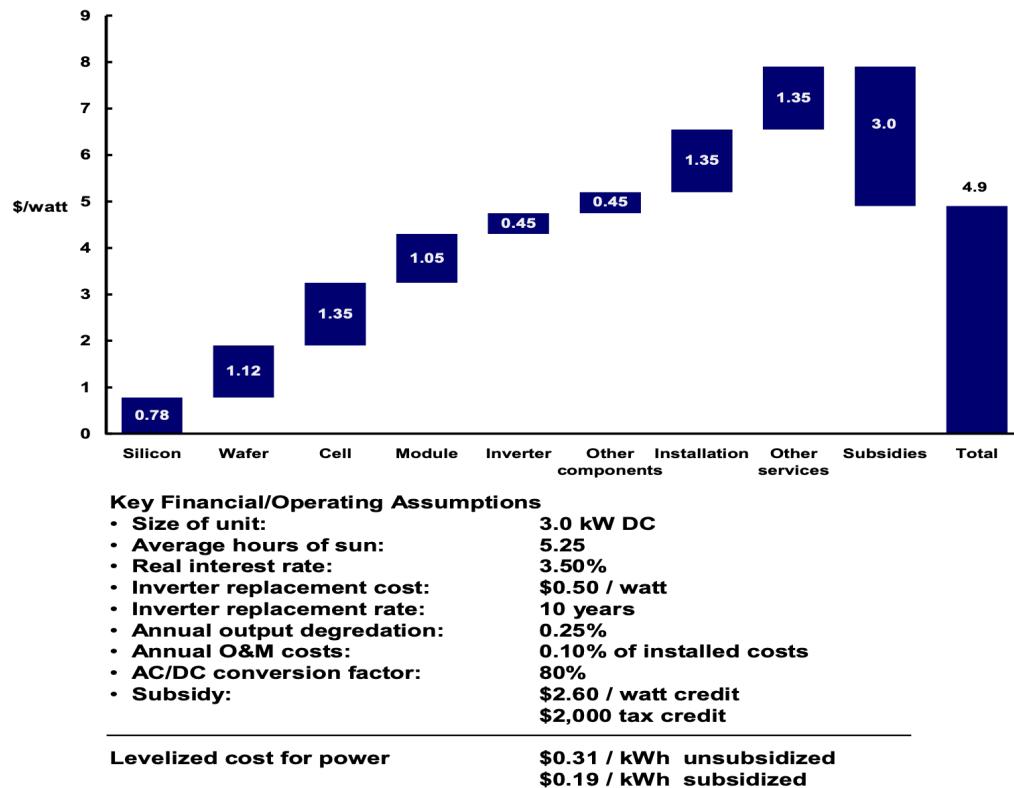
[25] Martin LaMonica, "Start-up Citizenre Thinks the Solar Power Industry Is Ready for a Radical New Way of Doing Business," *CNET News.com*, February 21, 2007.

Exhibit 1   *PV Module Manufacturing Volume and Price History*

	Annual Production		Cumulative Production		Average Price*	
	(MW)	Growth (%)	(MW)	Growth (%)	(US$/watt)	Growth (%)
1975			2		$30.00	
1976	2		4	100%	$25.00	-17%
1977	2	13%	6.25	56%	$20.00	-20%
1978	3	11%	8.75	40%	$15.00	-25%
1979	4	60%	12.75	46%	$13.00	-13%
1980	7	63%	19.25	51%	$12.00	-8%
1981	8	19%	27	40%	$10.00	-17%
1982	12	55%	39	44%	$9.00	-10%
1983	20	67%	59	51%	$7.75	-14%
1984	22	10%	81	37%	$7.00	-10%
1985	26	18%	107	32%	$6.50	-7%
1986	28	8%	135	26%	$5.00	-23%
1987	29	4%	164	21%	$4.00	-20%
1988	34	17%	198	21%	$3.75	-6%
1989	40	18%	238	20%	$4.25	13%
1990	47	18%	285	20%	$4.75	12%
1991	55	17%	340	19%	$4.50	-5%
1992	60	9%	400	18%	$4.25	-6%
1993	60	0%	460	15%	$4.25	0%
1994	70	17%	530	15%	$4.00	-6%
1995	80	14%	610	15%	$3.75	-6%
1996	89	11%	699	15%	$4.00	7%
1997	126	42%	825	18%	$4.15	4%
1998	153	21%	978	19%	$4.00	-4%
1999	201	31%	1179	21%	$3.50	-13%
2000	288	43%	1467	24%	$3.50	0%
2001	399	39%	1866	27%	$3.50	0%
2002	560	40%	2426	30%	$3.25	-7%
2003	759	36%	3185	31%	$3.00	-8%
2004	1195	57%	4380	38%	$3.25	8%
2005	1727	45%	6107	39%	$3.50	8%
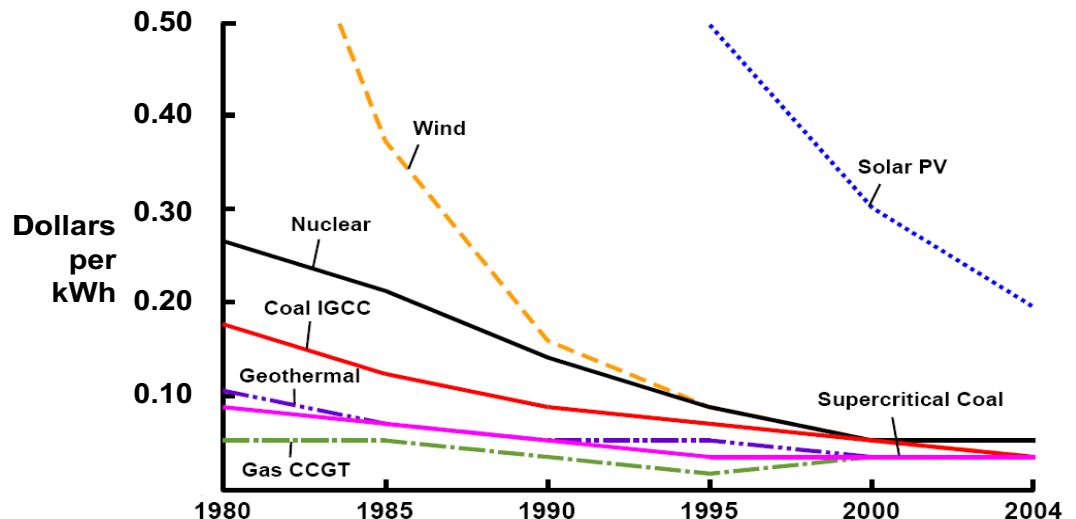
Source: Maycock

Exhibit 2   Breakdown of Typical Average System Price in California

Key Financial/Operating Assumptions
• **Size of unit:**	**3.0 kW DC**
• **Average hours of sun:**	**5.25**
• **Real interest rate:**	**3.50%**
• **Inverter replacement cost:**	**$0.50 / watt**
• **Inverter replacement rate:**	**10 years**
• **Annual output degredation:**	**0.25%**
• **Annual O&M costs:**	**0.10% of installed costs**
• **AC/DC conversion factor:**	**80%**
• **Subsidy:**	**$2.60 / watt credit**
	$2,000 tax credit

Levelized cost for power	**$0.31 / kWh unsubsidized**
	$0.19 / kWh subsidized

Source: Pacific Gas & Electric.

Exhibit 3   *Power Generation Cost by Technology*

Source: Cambridge Energy Research Associates

Exhibit 4   *California Average Retail Electricity Prices by Sector (US cents/kWh)*

	1980	1985	1990	1995	2000	2001	2002	2003	2004	2005
Industrial	4.84	7.7	6.89	6.93	7.77	10.67	10.49	11.32	11.67	10.49
Residential	5.61	8.08	10.28	11.55	11.25	12.3	12.56	12.78	12.53	12.89
Commercial	6.12	8.8	9.61	10.09	10.76	14.99	14.86	14.87	13.47	13.75

Source: California Energy Commission (http://www.energy.ca.gov/electricity/statewide_weightavg_sector.html)

Exhibit 5   ***Renewable Portfolio Standards***

State	% from Renewed Source	Year
Arizona	15%	2025
California	20%	2010
Colorado	20%	2020
Connecticut	10%	2010
Delaware	10%	2019
Hawaii	20%	2020
Illinois	8%	2013
Iowa	105 MW	
Maine	20%	2000
Maryland	9.5% (at least 2% from solar)	2022
Massachusetts	4% new	2009
Montana	15%	2015
Nevada	20%	2015
New Hampshire	25%	2025
New Jersey	20%	2020
New Mexico	20%	2020
New York	25%	2013
Oregon	25%	2025
Pennsylvania	18%	2020
Rhode Island	16%	2020
Texas	5,880 MW	2015
Vermont	Equal to load growth	2005-2012
Washington	15%	2020
Washington D.C.	11%	2022
Wisconsin	10%	2015

Source: The Pew Center on Global Climate Change.

Exhibit 6   Solar Electric Estimates for California, Texas and Massachusetts

	California	**Texas**	**Massachusetts**
Building Type	Residential	Residential	Residential
State & County	CA, Los Angeles	TX, Austin	MA, Middlesex
Utility	City of Los Angeles	Austin Energy	NSTAR
Utility Type	Municipal Utility	Municipal Utility	Investor-owned Utility
Assumed Average Electric Rate	$0.11	$0.09	$0.08
Assumed Average Monthly Electric Usage	983	983	983
Average Monthly Electricity Bill	$110	$92	$80
Solar Rating	Great (5.996 kWh/sq-m/day)	Great (5.192 kWh/sq-m/day)	Good (4.311 kWh/sq-m/day)
Solar System Capacity Required	4.00 kW of peak power (DC watts)	4.50 kW of peak power (DC watts)	5.50 kW of peak power (DC watts)
Roof Area Needed	400 sq-ft	450 sq-ft	550 sq-ft
Estimated Installation Cost (before rebates, incentives, tax credits)	$36,000 ($9/watt)	$40,500 ($9/watt)	$49,500 ($9/watt)
Expected Utility Rebate	$16,250	$13,500 ($4.5/watt installed, maxiumum $13,500, limited to 80% of cost)	$0
Expected State Rebate	$0 (state incentive does not apply to this utility)	$0 (state incentive does not apply to this utility)	$8,910 ($2/watt installed, maximum: $20,000)
State Tax Credit/Deduction	$0	$0	$1,000 (15% of net system cost, maximum: $1000)
Federal Tax Credit	$2,000	$2,000	$2,000
Income Tax on Tax Credit	$0	$0	$280
Estimated Net Cost	$17,480	$25,000	$37,870
Monthly Payment (6.5% apr, 30 years)	$110	$158	$239

Exhibit 6 (con't)   **Solar Electric Estimates for California, Texas and Massachusetts**

	Califonia	**Texas**	**Massachusetts**
Savings and Benefits			
Increase in Property Value	$11,460-$22,341	$9,480-$17,770	$8,200-$14,973
First-year Utility Savings	$573-$1,117	$474-$889	$410-$749
Average Monthly Utility Savings (over 25-year expected life of system)	$80-$156	$66-$124	$57-$105
Average Annual Utility Savings (over 25-year expected life of system)	$962-$1,875	$796-$1,491	$688-$1,257
25-year Utility Savings	$24,044-$46,874	$19,890-$37,283	$17,204-$31,420
Return on Investment (with solar system average cost set as asset value)	338%	191%	107%
Years to Break Even (includes property value appreciation)	<1 to 4 years	3 to 12 years	11 to 33 years
Greenhouse Gas (C02) Saved (over 25-year system life)	121.0 tons (242,000 auto miles)	121.0 tons (242,000 auto miles)	121.0 tons (242,000 auto miles)

Source: Findsolar.com
Findsolar.com is a joint partnership between the American Solar Energy Society, Solar Electric Power Association, Energy Matters LLC, and the U.S. Department of Energy.

Exhibit 7   ***SunPower Financial Statements***

SunPower Corp. Balance Sheet

	30-Jun-06	31-Dec-05
Assets		
Current assets		
Cash and cash equivalents	$277,493	$143,592
Short-term investments	19,900	
Accounts receivable, net	34,263	25,498
Inventories	21,566	13,147
Prepaid expenses, net of current portion	19,888	3,236
Total current assets	373,110	185,473
Property and equipment, net	136,436	110,559
Goodwill	2,883	2,883
Intangible assets, net	16,389	18,739
Advances to suppliers, net of current portion	13,429	
Total assets	$542,247	$317,654
Liabilities and Stockholders' Equity		
Current liabilities		
Accounts payable	$22,173	$14,194
Accounts payable to Cypress	3,262	2,533
Accrued liabilities	10,878	4,541
Current portion of customer advances	11,504	8,962
Total current liabilities	47,817	30,230
Deferred tax liability		336
Customer advances, net of current portion	30,609	28,438
Total liabilities	78,426	59,004
Total stockholders' equity	463,821	258,650
Total liabilities and stockholders' equity	$542,247	$317,654

Source: Edgar Online.

Exhibit 7 (con't)   SunPower Financial Statements

SunPower Corp. Income Statement
(in thousands, except per share data)

	Three months ended, June 30,		Six months ended June 30,	
	2006	**2005**	**2006**	**2005**
Revenue	$54,695	$16,400	$96,653	$27,492
Costs and expenses				
Cost of revenue	43,248	17,585	79,514	30,678
Research and development	2,588	1,360	4,584	3,027
Sales, general and administrative	4,985	2,203	9,366	4,003
Total costs and expenses	50,821	21,148	93,464	37,708
Operating income (loss)	3,874	(4,748)	3,189	(10,216)
Interest income (expense), net	1,569	(1,398)	2,403	(3,184)
Other income (expense), net	353	(190)	490	(173)
Income (loss) before income tax provision	5,796	(6,336)	6,082	(13,573)
Income tax provision	412		443	
Net income (loss)	$5,384	($6,336)	$5,639	($13,573)
Net income (loss) per share:				
Basic	$0.08	($0.36)	$0.09	($1.29)
Diluted	$0.08	($0.36)	$0.08	($1.29)
Weighted-average shares:				
Basic	64,040	17,614	62,583	10,508
Diluted	69,408	17,614	68,172	10,508

Source: Edgar Online.

Exhibit 8   ***Key Drivers of Crystalline Module Cost Reductions***

Driver of cost savings	
Economies of scale	Gains in purchasing, efficiency improvements and reduction of overall breakage/downtime due to economies of scale (often >3 cents/watt/year for largest players)
Module efficiency improvements	Slow but steady reduction of ~1/2 kilogram of silicon per watt each year as module efficiency increases and wafers get thinner (1-2 cents/watt/year in cost savings).
Lower cost materials	Shifts to lower cost materials for stringing, framing, backing, and packaging (1-2 cents/watt/year)
Lower depreciation	Lower depreciation expenses with lower capital costs for manufacturing equipment (varies by company and by accounting standards; often >2 cents/watt difference depreciation expense for new, lower cost/watt manufacturing equipment and previously purchased equipment)
Lower wages	Move to lower wage locations such as China or India (cost reduction >2 cents/watt for some manufacturers)
Narrower range of technologies/customers	Standardization of process by focusing on narrow range of technology (e.g. "we want to be the lowest cost producer of multicrystalline cells anywhere in the world") or focusing on specific customers when manufacturing/delivery logistics are easier

Source: Michael Rogol, SunScreen.