1

SOLAR ENERGY

Scaling Up Manufacturing and Driving Down Costs

Above the tree-lined streets of Pasadena, California, in the sleek, open-air offices of high-tech start-up incubator Idealab, a team of researchers is huddled around a strange-looking device that concentrates the light of the sun and generates on-site electricity. Bill Gross, Idealab's founder and the CEO of upstart concentrating-solar PV company Energy Innovations, beams with the nerdy excitement of a computer programmer who's just created a nifty chunk of code or a biologist who's uncovered a new genome. "The economic potential for solar is enormous," says Gross. "Within a decade, solar will reach price parity with other energy sources." His vision is to replicate Idealab's rooftop, where a dozen solar-concentrator demo units track the sun from dawn to dusk. He wants Energy Innovations units sprouting on commercial and industrial roofs around the world, providing low-cost, efficient, distributed electric power from the sun.

Gross, whose Idealab hatched such Internet winners and losers as Citysearch, eToys, Overture, and Tickets.com, is now in a race to develop his solar technology and bring it to market before other firms, such as Practical Instruments, SolFocus, and Solaria. He firmly believes that the future belongs to those who can help solve two of our world's most pressing issues, energy and water—global access to clean, reliable, and abundant sources of each. His solar technology company—which aims to use relatively inexpensive mirrors to reflect the light of the sun onto expensive high-efficiency solar cells—raised more than $40 million in 2005 and 2006, with hopes of putting its first commercial products onto rooftops in 2007.

Energy Innovations represents just one of the many technological developments taking place in the rapidly expanding solar industry. These developments include everything from incremental improvements in the most abundant form of solar electricity—silicon-based solar PV—to new nonsilicon forms of solar electric generation, including nanotechnology-based innovations and CIGS (copper, indium, gallium, selenium). The variety of emerging solar electric technologies and applications demonstrates the richness of opportunity in an industry expanding by more than 30% per year since the mid-1990s.

What does this mean for investors, entrepreneurs, and others who want a piece of the growing solar pie? The solar business, once the domain of back-to-the-earth zealots and government and corporate research labs, is now being embraced by nimble, visionary entrepreneurs with access to capital, skilled management, and business acumen. Also joining the race are established multinationals such as Applied Materials, GE, and Sharp—companies that are basing their future, at least in part, on corporate spoils in the solar industry.

RAPID FIRE

Part of the growing interest in solar power has to do with the sector's astounding growth rate. In 2000, the total annual manufacturing output of all solar companies was about 300 MW. In 2005, solar industry manufacturing output rose almost fivefold to more than 1,500 MW of solar PV modules and surpassed 2,000 MW in 2006. That's enough electricity-generating capacity to serve two cities the size of Atlanta for an entire year.

The entry of multinationals and large, well-funded, publicly traded solar companies into the space provides opportunities for individual and institutional investors to put money into some of the more promising companies and developments. In 2005 and 2006, for example, solar companies such as SunPower and China's Suntech Power Holdings had successful initial public offerings on U.S. stock exchanges and global giants such as Applied Materials joined longtime corporate solar stalwarts such as BP and Sharp.

Although current solar power costs can be prohibitive in some regions, solar systems can make a great deal of sense in regions that have high-

utility costs, offer solar subsidies, or are blessed with a preponderance of sunny days—offering opportunities to a new class of systems integrators and financiers. As we discuss below, some companies are packaging systems and financing in such a way that solar can cost less for the customer from first day of use—including builders of new homes who are integrating solar systems into mortgages and firms that have developed unique financing options.

The solar landscape is filling up with a range of new companies and business models, offering opportunities for qualified entrepreneurs, managers, and workers to join current efforts in solar manufacturing, financing, installation, systems integration, and elsewhere along the solar value chain.

Solar's challenges, however, are many. They include entrenched interests that support fossil fuels over clean energy, shortsighted rather than long-term policies and incentives that disrupt growth, nonuniformity among utility districts that makes consistent standards and protocols nearly impossible, and cost barriers that have kept solar from reaching cost parity with retail electric rates. But like any high-growth technology innovation story, solar is in a unique position to overcome many of these challenges and change the world in ways unimaginable.

BRINGING SOLAR DOWN TO EARTH

Invented at Bell Labs in the 1950s and commercialized in the 1970s, solar PV has moved from a niche industry powering space satellites to a mainstream business with such well-known multinational players as BP, GE, Sharp, and Shell and pure-play efforts such as Evergreen Solar, First Solar, Q-Cells, SunPower, and Suntech Power. Since the mid-1990s, the industry has looked eerily similar to the consumer electronics revolution that preceded it—with annual growth rates in the 30% to 60% range.

Solar is becoming big business, representing more than $11 billion in global sales in 2005, more than $15 billion in 2006, and a projected $60 billion–plus in 2016, according to Clean Edge research. In 2005, venture capitalists poured more than $150 million into deals based in North America, such as Advent Solar, HelioVolt, Energy Innovations, Miasolé, and Nanosolar. Nearly $1 billion was raised via initial public offerings (IPOs) in Europe and the United States for SunPower, Suntech Power, and

Q-Cells; those companies' IPOs represented three of the largest technology offerings of 2005.

Piper Jaffray clean-energy analyst Jesse Pichel highlights what the excitement is about. "Our investment partners like solar because it leverages advances made in the semiconductor space," he says. "Our investors understand semiconductors—and are therefore more comfortable with solar than many other emerging energy sectors."

Because of the nature of the solar business, it is the *electronics* giants in the solar industry, such as Sharp, Sanyo, and SunPower, that are likely to be the big winners, rather than the energy giants such as Shell and BP. And as highlighted below, it will likely be the domain of new nimble start-ups that are leveraging lessons learned from earlier semiconductor manufacturing revolutions.

THE SOLAR "EXPERIENCE CURVE"

Even though there is no such thing as a subsidy-free energy source (oil, natural gas, coal, and nuclear are all heavily subsidized), solar still must reduce its overall cost to become truly competitive. And that's exactly what's been happening. As cumulative global output from solar soared from 5 MW in 1979 to more than 2,000 MW in 2006, the wholesale price of a solar PV module dropped from $32 per watt to about $3 per watt—roughly a 50% drop per decade.

And solar, we believe, is poised to reach significantly lower costs and prices in coming years. Technology advances, market growth, increased competition, and economies of scale in manufacturing are all playing a big part in this transformation. Solar PV manufacturing has benefited from fairly constant, decades-long progress in fabrication technology, which has shrunk solar cell weight and thickness while harnessing sunlight more efficiently.

Dr. Richard Swanson, who founded PV cell maker SunPower in 1985 while teaching electrical engineering at Stanford University, is one of the solar industry's most respected experts on declining technology costs. The costs of PV modules, says Swanson, have moved in a "classic experience curve," where product costs fall in direct correlation to increased worldwide production volume. Prices fall about 18%, reckons Swanson, for every doubling of cumulative production volume.

In the late 1990s, his company's innovations and growth caught the attention of Cypress Semiconductor CEO and noted chip industry maverick T.J. Rodgers. Cypress bought a majority interest in SunPower in 2002, signifying a major confluence of high tech and clean tech. SunPower is now public, its IPO rekindling memories of the earlier high-tech heydays when its share value jumped 41% on its first day of trading in November 2005.

HIGH-VOLUME, LOW-COST MANUFACTURING

Suppose you could accelerate the learning curve and drive down costs even more rapidly than occurs in the classic "experience curve"? One person who's explored this concept is former Hewlett-Packard (HP) executive Marvin Keshner. He wrote a report with coauthor Rajiv Arya for the U.S. Department of Energy's National Renewable Energy Lab (NREL) in 2004 entitled "Study of Potential Cost Reductions Resulting from Super-Large-Scale Manufacturing of PV Modules." The authors reported on the concept of a massive solar production facility that could enable the production and installation of $1-per-peak-watt solar systems; the average cost for solar in 2006 was roughly $6 to $8 per peak watt installed. Some of the innovations they envisioned include the use of materials optimized for a 25- to 30-year operating life, driving down costs by minimizing transportation and handling expenses and eliminating intermediaries, automating factory processes to reduce breakage and increase yields, developing modular lines that can be rotated for planned downtime and maintenance, and dramatically scaling up the size of solar manufacturing facilities. Today, Keshner is heading up a new solar venture that is working to drive down costs by implementing many of the recommendations outlined in his report.

It's not surprising that an HP executive would take up an interest in solar. Indeed, many of the same companies and entrepreneurs that innovated and built profitable integrated-circuit, flat-panel, and disk-drive manufacturing businesses are poised to win in next-generation solar. They're applying to the solar industry the same expertise they've gained in applying conductive materials onto substrates and in ramping up low-cost, high-volume, continuous-flow, semiconductor-based manufacturing processes.

In fact, many current and emerging clean technologies take advantage of manufacturing breakthroughs perfected in the computer and high-tech industries. As in the high-tech revolution before it, semiconductor-based chips and circuits also lay at the heart of grid innovation and energy delivery. Semiconductors—silicon-based devices such as microprocessor chips and transistors—have shaped our modern era by enabling the mass manufacturing of computers, radios, TVs, and other consumer electronics. But something equally striking is happening at the intersection of semiconductors and energy—increasingly semiconductors are *becoming* the energy source. The first semiconductor revolution enabled the proliferation of computers and consumer electronics, while the second semiconductor revolution is literally powering our homes, cars, and a range of other consumer products.

In the heart of Silicon Valley, Miasolé in Santa Clara, California, is one example of a company applying manufacturing breakthroughs from the disk-drive space to the solar industry. Miasolé founder and CEO David Pearce and his team are leveraging a unique form of sputtering technology that they originally developed and applied to high-volume coating processes for the production of hard disks for the data-storage industry. Now the company is using the same process to enable low-cost manufacturing of thin-film solar technologies. Since 2005, Miasolé has raised more than $51 million from such seasoned investors as Kleiner Perkins Caufield & Byers to help deliver on its plan.

HIGH STAKES

Keshner and Pearce, of course, aren't alone in working to adapt technologies from traditional semiconductor manufacturing and applying them to a new era of low-cost, large-scale solar production. The list of innovators is long, and the stakes are high.

Large electronics companies such as Sharp, for instance, have understood the connection between semiconductors and energy for decades. The Japan-based company, a leader in consumer electronics and flat-panel displays, committed itself to being a leader in solar power in the 1960s. Today, it is the world's leading manufacturer of solar PV modules, representing more than a quarter of global solar PV output, with annual revenues of more than $1 billion from that business. The company's president,

Katsuhiko Machida, predicts that the cost of generating solar power could fall by half between 2006 and 2010, and he's targeting approximately 20% of the company's revenue from its solar division by the end of the decade.

Q-Cells, the German solar cell manufacturer, provides another interesting example. The company, based in Thalheim, Germany, went from zero manufacturing output in 2000 to being the world's second largest manufacturer of solar cells in 2006. Q-Cells planned to manufacture about 250 MW of solar cells in 2007.

Solaria, a concentrating solar company in Fremont, California, is taking fabrication technologies used in contract semiconductor manufacturing and applying them to concentrated solar power. The company raised $22 million in series B financing in 2006 from venture capitalists and strategic investors, including Q-Cells. The company aims to drive down the cost of solar modules by replacing silicon with an inexpensive concentrating layer. Unlike some of its competitors that are working on high-concentration solar developments (up to approximately 500 times concentration), the company is focused on low concentration of two to three times. The company's products require no moving parts and have a form factor nearly identical to today's flat solar panels.

And as mentioned earlier, the leading semiconductor equipment manufacturer for the chip industry, Applied Materials in Santa Clara, California, is now taking aim at the solar industry. What this all means is that the same technologies that have driven down computer chip and PC costs since the 1980s are now being used to drive down solar-cell and module costs. The industry will increasingly become a commodity-driven business, which means it will likely be won by those companies, like electronics manufacturers, who know how to thrive in a competitive commodity environment. And in the same way that the computer industry spawned value-added resellers who provided add-on services, the solar business offers big opportunities for its share of systems integrators and value-added systems packagers.

BREAKTHROUGH OPPORTUNITY

The $2-Watt Solar Photovoltaics System

It goes without saying that one of the biggest opportunities for solar entrepreneurs is getting the cost of solar to cost parity with conventional retail electricity. While the big players such as Sharp and Kyocera continue to drive down costs, it may be one of the new entrants to really rock the boat with breakthrough technology and significantly lower pricing. Players such as Miasolé, Nanosolar, HelioVolt, and Q-Cells could be the first to deliver a truly low cost solar cell or module. Watch out for a current or emerging player that can bring the cost of an entire solar PV system to around $2 per peak watt—the equivalent of $5,000 for an average-sized 2.5-kW (2.5-kilowatt) residential rooftop system, for example. Systems priced at this level would provide electricity at less than 10 cents per kilowatt-hour (kWh), beating out most customers' retail utility rates throughout the United States. Someone, we believe, is likely to break this price barrier by 2015—paving the way for a low-cost, ubiquitous, solar future.

SYSTEMS THINKING

It's important to note the distinction between the cost of a PV module (approximately $3 to $4) and the retail price actually paid for a full solar PV system for a home or business, known in the industry as the *installed* price. Installed price includes the cost of inverters that change the sun's direct current (DC) to usable alternating current (AC), other integration components, racks to mount the modules, and installation and connection service fees. The installed price is typically at least double the wholesale solar module price.

That's $6 to $8 per watt in the United States today, without any subsidies, which translates to approximately 18 to 36 cents per kilowatt-hour (depending on the application, finance charges, and other variables)—still very expensive compared with most utility rates of less than 10 cents per kilowatt-hour.

On a direct-cost basis, solar compares favorably only in specific circum-

stances: in countries and regions with extremely high utility costs, such as Japan and San Diego; in states with generous solar rebates, such as New Jersey and California; and at high-demand times, such as hot summer afternoons when utilities must draw on their expensive "peaker" plants to keep power-hungry air conditioners running. The good news for solar is that those sultry afternoon hours also provide the most sunlight, making PV an attractive option for peak demand. Remember, however, that it's the sun's light, not its heat, that is converted to electrons in the photovoltaic process. Solar modules are actually less efficient at very high temperatures, so a rooftop system on a clear 70-degree day in Seattle produces more power than the same-size system broiling under 110 degrees in Phoenix.

To be competitive with conventional grid power in most markets, solar PV has to be available for $2 to $2.50 per watt installed, which would generate power at 5 to 12 cents per kilowatt-hour. Ever-higher spikes in natural gas and coal-fired power, of course, would lower the comparative bar for solar and accelerate the crossover point. But even without fossil-fuel price jumps, SunPower's Swanson and others see solar PV prices falling by the same rate—50% per decade—as they have since the mid-1980s. And solar power costs may soon decrease even further because of advanced technology development. On the technology front, a raft of start-ups in Silicon Valley and elsewhere, many well funded by the leading lights of venture capital, are working on innovative tech breakthroughs to make solar cells lighter, thinner, faster to manufacture, and, above all, cheaper.

Companies that are working to drive solar prices down with potentially disruptive, nonsilicon technologies include Konarka, Miasolé, Nanosolar, and Nanosys. Instead of silicon, these photovoltaic materials include nanostructured titanium dioxide (Konarka); CIGS (Miasolé and Nanosolar); and nanocomposites, which refer to multiple materials reengineered at the molecular, or nanotechnology, level (Nanosys). All of these aim to disrupt the cost structure, conventional size, and customary manufacturing methods of traditional solar cells.

Others, such as First Solar, are using cadmium telluride technology, while still others, including United Solar Ovonic, are pursuing innovations in silicon-based thin-film technologies. And the larger players are involved as well, including the likes of Shell, Sharp, and even Honda. Instead of building wafer-sized solar cells, these firms are variously sputtering, printing, or stamping flexible, lightweight solar cell architectures on foil and

polymer substrates, often in a continuous, roll-to-roll manufacturing process. As a result, solar cells can literally be peeled off a polymer roll rather than produced as the traditional hard, brittle, crystalline panels.

SILICON SPEED BUMP?

But even as clean energy leverages technology advances and market growth into lower costs, there's another economic fundamental that can have the opposite effect: a shortage, and resultant cost increase, of the raw material needed to produce the product. Since 2004, solar PV has experienced just that, with a worldwide shortfall of PV-grade silicon that's made it difficult, and more expensive, for manufacturers to keep up with soaring worldwide demand. Japan and Germany, in particular, are to solar PV what China and India are to oil—fast-growing markets putting a crimp on supplies for the rest of the world.

The good news is that the world has plenty of silicon—it's the second most common element in the earth's crust, trailing only oxygen. There's no shortage of sand, feldspar, quartz, and other minerals that serve as the raw materials for what the solar PV industry calls silicon feedstock. For many years, with the size of the solar power business a mere blip compared with the global semiconductor industry, PV manufacturers were able to rely on scrap silicon from high tech's wafer-fabrication facilities. By 2008, however, the solar industry is projected to surpass the high-tech semiconductor industry as the largest consumer of raw silicon feedstock—a truly historic milestone in solar's growth history.

To address the current shortage, silicon manufacturers are ramping up production of solar-specific feedstock. The world's largest polycrystalline silicon producer is Hemlock Semiconductor, a joint venture of Dow Corning and two Japanese manufacturers. Hemlock is increasing capacity at its plant outside Saginaw, Michigan, by 50% in a $500 million expansion that's adding 150 full-time and 400 contractor jobs in the economically depressed region. With producers such as Hemlock gearing up, solar industry executives figure the current supply shortfall will last only 2 to 3 years, with traditional cost decline trends returning after that.

Solar Grade Silicon, based in Moses Lake, Washington, a division of Norway-based REC, was the first silicon manufacturer to focus exclusively on the solar industry. It's currently in the process of doubling its manufac-

turing capacity from 6,500 metric tons to 13,000 metric tons annually. Other companies that are also ramping up silicon production for the solar industry include Wacker Chemie AG, based in Munich, and Tokuyama, a chemical group based in Japan.

We believe the shortage of silicon will dissipate, if not disappear, sometime before 2010. At that point, we believe that silicon suppliers will have begun to bring enough silicon feedstock online to meet the needs of both the global solar PV and computer-chip industries. In addition, new technologies that reduce the need for silicon or replace silicon altogether will offer relief. There will be some turbulence on the road ahead as solar PV and silicon feedstock manufacturers provide each other with the right market signals as they both ramp up production, but we expect the resumption of lower costs as the silicon market normalizes.

BREAKTHROUGH OPPORTUNITY

Concentration

A number of players are competing to develop solar PV systems that get more power out of the sun by concentrating its solar rays. The technology is called concentrating PV (CPV). It's a diverse group, including those using low-scale concentration, such as Solaria and Stellaris, and others going for high-scale concentration, such as Concentrix, Energy Innovations, Practical Instruments, and SolFocus. It also includes a number of companies that aren't using PV at all—but are concentrating the sun to heat oil and turn turbines to create electricity. These include players such as Stirling Energy Systems and Solargenix (now a subsidiary of Spain-based Acciona), pursuing a long-term opportunity for desert-based, utility-scale solar. One issue for high-concentration players: The technologies require moving parts, which adds complexity and the potential for breakdowns. But for investors and businesses, the solar concentration market is clearly heating up.

THE INSTALLATION GAME

One company riding the wave of falling solar energy prices to impressive growth is PowerLight in Berkeley, California. PowerLight, acquired by SunPower in 2007 for $332.5 million, is the leading systems integrator and installer of commercial and industrial systems in the United States. PowerLight president Dan Shugar, an intense, hyperactive guy who gets his full money's worth out of a swivel chair, can easily rattle off the firm's annual revenue totals for the past several years. From its first million in 1996 to $92 million in 2004, PowerLight has parlayed dozens of large commercial solar systems integration projects to a spot in the *Inc.* 500 Hall of Fame. PowerLight shares that honor, for being listed for 5 straight years among the nation's fastest-growing privately held companies, with the likes of Microsoft and Oracle.

PowerLight isn't shy about cheerleading. In its corporate office in a renovated former Heinz ketchup factory near the shores of San Francisco Bay, shiny blue crystalline photovoltaic modules are everywhere—wall decorations, cubicle partitions, tabletops. Venues where PowerLight rooftop PV systems silently crank out electrons include U.S. Navy bases in Pearl Harbor and San Diego, several Napa Valley wineries, FedEx's California air hub in Oakland, San Francisco's Moscone Convention Center, several Lowe's home improvement stores, a resort hotel on Hawaii's Kona coast, and the Las Vegas Valley Water District. In 2005, PowerLight completed what was then the world's largest solar PV generating plant, the 62-acre, 10-MW Bavaria Solarpark in southern Germany. All told, PowerLight systems produce about 100 MW of energy; Shugar proudly points out that that's more than three times the world's entire solar PV production in 1990, the year he started in the business.

Solar power can't yet compete with centralized wind or fossil-fuel grid power on a straight cents-per–kilowatt-hour basis, so PowerLight customers, like all users of solar, must take a long-term payback view. "Our customers are essentially financing a power plant with all the fuel up front," says Shugar. "You have to be willing to look at life-cycle costing. Being super short-term focused won't get it done."

Alameda County, California, is the home of progressive-minded cities Berkeley and Oakland and the nation's first major wind farms (dating to the 1970s) at Altamont Pass, but county officials approach capital energy

projects as soberly as any local government under a twenty-first-century budget squeeze. Matt Muniz, energy program manager for the county, says projects must meet a specific annual investment hurdle rate over a 25-year project life, including debt service and interest. "It's all based on how much power we can generate that we don't have to buy," he says. The county compares its project investment against a forecast of 2.5% annual increases in electric rates from utility PG&E (where Shugar once worked in solar R&D), which Muniz admits is conservative; PG&E's base rate jumped 6% in January 2006.

Solar PV systems from PowerLight generate electricity for seven Alameda County facilities, including the roof of an Oakland courthouse and the offices of county emergency services and environmental health services. The first and by far the largest project is the 3-acre solar array on the roof of Santa Rita Jail, a sprawling facility used by author Tom Wolfe as the site of key character Conrad Hensley's incarceration (and escape, when an earthquake destroys the prison) in his 1998 best seller *A Man in Full*. The real-life Santa Rita houses 4,200 inmates and 500 prison employees near the suburb of Dublin, and its 1.18-MW installation is one of the largest solar roofs in the United States.

When Muniz and his colleagues first considered solar power for the jail in 2000, the economics didn't work. Average electric rates from utility PG&E were less than 7 cents per kilowatt-hour, so in the first 500-kW phase of the project, PowerLight offered energy-efficiency improvements, such as a better water chiller for air-conditioning, to augment its solar generation. The following year brought the infamous summer of rolling blackouts and Enron market manipulation as California's deregulation energy crisis hit, and utility rates nearly doubled. "We took another look at the economics," says Muniz, "and in phase two we didn't need the efficiency measures to get the payback." Phase two added another 180 kW, and the final phase (three, completed in 2002) brought an additional 500 kW.

PV panels now generate as much as half of the jail's peak power on bright summer afternoons. Throughout the year, solar contributes an average of 20% of the daytime juice and 12% overall, since solar panels can't harness any sun after dark. "I was hoping we might get something from the light of a full moon," Muniz jokes, "but I guess the technology isn't quite advanced enough yet."

BREAKTHROUGH OPPORTUNITY

Integrated Photovoltaics

For solar to become truly ubiquitous like computers, cell phones, and the Internet, it will have to be embedded into everything from portable electronic devices to roof tiles to glass. Consider it the ultimate disappearing act, with solar cells integrated into daily products and services. A number of players are already doing this for the home-building industry, including Sharp and PowerLight, which both offer residential solar roof tiles. Perhaps the largest opportunity right now is among roofers and builders in California, where they can take advantage of the state's Million Solar Roofs incentives along with federal tax credits to bring down costs. Homebuilders such as Clarum Homes, Centex, Grupe Company, and Lennar are starting to build entire developments with solar BIPV (building-integrated photovoltaics). Increasingly, BIPV could become a standard option on new homes not just in California but also around the United States.

THE POWER OF FINANCE

Breakthroughs aren't happening only at the technology level.

In the electric power business you've got Con Edison, Commonwealth Edison, Detroit Edison—why not a SunEdison, the utility that delivers 100% solar power? Indeed there is one, but the "utility" actually generates its power right on the roof of your retail location or product warehouse. SunEdison LLC, based in Baltimore, is one of several clean-tech companies building a growing business on innovative finance techniques. SunEdison secures investor financing for each project, builds the solar PV array and assumes the payback risks, then sells the power to the customer under the roof for a fixed rate—usually at or below current utility rates. Like PowerLight, SunEdison requires a long commitment—a 10- or 20-year contract. Customers, including a Whole Foods Market store in Edgewater, New Jersey, and three Staples distribution centers in New Jersey and California, typically save about 5% on their annual energy bills and earn renewable energy credits.

SunEdison's model took top honors in the 2004 Harvard Business School business plan competition's social enterprise track, and the following year it attracted even better and more lucrative attention. In June 2005, Goldman Sachs and Hudson United Bank combined to form SunEdison's $60 million SunE Solar Fund I, projected to finance 25 solar roof projects across the United States. The fund covers construction loans, senior term loans, and partnership equity.

To make the numbers work, SunEdison typically operates in states with generous solar rebate programs for commercial projects: California, Connecticut, Hawaii, Illinois, Massachusetts, Nevada, New Jersey, Oregon, and Rhode Island. But that's starting to change; the firm typifies the solar industry's gradual transition from subsidy dependence to more of a bottom-line focus. In an effort to reduce costs by up to 20% from economies of scale, SunEdison raised its minimum PV array size to 500 kW, after an earlier increase from 100 to 280 kW. The firm also benefits from its exclusive relationship with BP Solar, the solar unit of the global energy conglomerate that likes to say its initials stand for *Beyond* (instead of its original name *British*) *Petroleum*. Unlike other small PV firms, SunEdison receives a guaranteed supply of panels from its very large partner. In 2006, the company also shored up its installation capabilities by acquiring Sacramento-based systems integrator and installer Team Solar. SunEdison's model, along with others such as that of MMA Renewable Ventures, solves the significant issue of up-front capital costs for solar power.

"The next five to seven years," says young SunEdison founder and CEO Jigar Shah, "are going to be all about costs. Rebates will be tight—a state like New Jersey has a fixed amount of money to devote to clean energy, and more and more projects will be competing for it. It's becoming a zero-sum game, and the lowest-cost providers will win." SunEdison is truly putting that model to the test with its largest project—one of the largest solar PV projects in the world, in fact. It's an 18-MW solar "farm" covering several square miles in the Nevada desert outside Las Vegas, and the customer is the U.S. military.

BREAKTHROUGH OPPORTUNITY

Sell Electrons, Not Systems

Photovoltaics (PV) modules represent about half the cost of a solar PV system. So-called balance-of-system components such as inverters and racking, along with installation, make up the remaining cost for putting in a system. To cover the considerable up-front costs of solar—as well as capture the tax benefits for those willing to take the risk—a number of innovators such as SunEdison and MMA Renewable Ventures are pulling together financing and systems packaging to lower the end cost for business owners. Instead of selling entire systems to end users, they sell or lease electrons. Their financial models are interesting and complex—and offer a unique opportunity to entrepreneurs and bankers. We believe there's an opportunity for both new national and regional players to compete in this emerging financing market—making solar more affordable for companies and building owners.

DRIVING EFFICIENCY

As the solar industry drives down costs across the value chain, it also needs to focus on another key issue: efficiency. Cell efficiency refers to how much sunlight a solar PV cell converts into electricity—so, for example, a 15% efficient cell can convert about 15% of the sunlight hitting its surface into electricity. Today's average silicon-based solar cell gets around 17% efficiency. In October 2006, SunPower, a leader in the quest to increase cell and module efficiency, said it reached 22% efficiency at the cell level. But what if a solar cell could get to 50% efficiency? This would mean you could more than double or triple the amount of electricity coming out of today's average solar modules—using the same square footage of solar material.

In the race for solar cell efficiency breakthroughs, as in many areas of clean tech, the U.S. military is at the forefront of pushing technological boundaries. In 2005, the Pentagon's DARPA (Defense Advanced Research Projects Agency) announced a $30 million program to more than double

the efficiency of solar cells. Dubbed the Very High Efficiency Solar Cell (VHESC) program, the effort is targeting a new breed of solar cells with efficiency rates more than double those of conventional current solar cells. The best commercially available solar cells today have efficiency rates of around 20%. The VHESC program is targeting efficiency rates closer to 50%.

This could make accessible the holy grail in distributed PV: low-cost, lightweight, extremely efficient solar cells. VHESC team coleader Dr. Alan Barnett, former CEO of AstroPower (a solar company that went from boom to bust and was eventually acquired by GE) and now a professor at the University of Delaware, explains the significance. "Our soldiers carry more mission-critical electronic devices than ever before—which requires a huge amount of energy in the form of batteries," he says. "The first shipment of batteries sent into Iraq needed to be flown in on three cargo planes and weighed more than five hundred forty tons," or the equivalent of more than 200 Hummer H3s. This can be a logistical nightmare. The military aims to figure out how to significantly lighten the load of soldiers by reducing the need for conventional batteries while meeting the needs of the modern soldier.

The VHESC consortium, led by the University of Delaware, is also receiving support from such corporations as DuPont, BP Solar, and Corning and involves more than 10 other universities and laboratories, including NREL, Massachusetts Institute of Technology (MIT), Harvard, Yale, and Carnegie Mellon. The programs could see total project funding of more than $50 million from its military and corporate donors. If successful, the program could enable a new class of integrated solar-powered devices for military use. This means that rather than carrying backup batteries for their myriad communication devices, global positioning system (GPS) equipment, and night-vision goggles, soldiers would carry devices powered by the sun. Others have talked about this vision before, but the project's unique approach to ultra-high-efficiency solar cells sets this effort apart.

Barnett says this represents the *largest single government investment to date* in solar research and could translate into some significant commercial applications. "You could charge your entire laptop in just one hour—all from the power of the sun," he explains.

But the military isn't waiting around for 50% efficient cells to get into solar procurement. In Hawaii, the U.S. Army is deploying 7 MW of solar

energy to power thousands of military homes in a new development on Oahu. The system is designed to reduce use of fossil fuels by 30% for an entire complex of 7,894 new and renovated homes. The army development is currently the largest known planned residential solar project of its kind. And as we point out in chapter 7 ("Mobile Technologies: Powering a World on the Go"), the military is using solar technology to provide power to soldiers in the field.

Taking a page from the military's book, NASA and other space agencies have also been some of the earliest investors in emerging clean technologies. The thriving global solar power industry, now valued at nearly $15 billion annually, arguably has the space industry to thank for its existence. NASA was one of the first large-scale customers of solar cells for the deployment of solar-powered satellites, starting back in the 1960s. Solar cells cost hundreds of dollars per watt back then, compared with less than $4 per watt today. Investing in the developing technology for use in outer space, NASA helped bring solar PV prices out of the stratosphere and down to earth, putting the solar industry on a path to the mainstream corporate and investment opportunity that it is today.

THE BIG BUSINESS OF SMALL

While there is no single definition for nanotechnology, most scientists and technologists who work in the sector agree that nanotechnology is generally the manipulation of matter at a very tiny scale—from 1 to 100 nanometers. To put this scale in perspective: an average human hair is 50,000 to 100,000 nanometers wide and a sheet of paper is about 100,000 nanometers thick. In other words, you could stack a thousand nanodevices side by side to equal the thickness of either paper or a human hair. Using advances in nanotechnology, solar scientists are creating materials at the molecular level that could enable similar advances as those seen in the chip industry—lower costs, higher efficiency, and increasingly smaller devices.

Nanotechnology and clean tech are in many ways a natural fit. Many of the large corporations that are active in clean tech are also active in nanotech. Nanotech could end up enabling many next-generation clean technologies such as advanced batteries, water-desalination and water-filtration membranes, building insulation, and of course, solar power. "I strongly

believe that nanotech holds the ability to push a number of clean technologies' costs, in particular solar, down dramatically," says Scott Mize, a nanotech entrepreneur, advisor, author, and speaker. "In a lot of areas it is the missing ingredient in getting clean-energy technologies over the line. Nanotech—and remember that most semiconductor technologies today are now nanotechnologies—could enable a new breed of low-cost energy sources and more."

Nanosolar, whose name bespeaks its mission, is pairing nanotech innovations with advanced thin films to embed solar cells into roof tiles and achieve other tech breakthroughs to make solar power cheaper and easier to deploy.

The company, based in Palo Alto, California, is attempting to dramatically scale up manufacturing processes while significantly lowering prices. The company plans to do this without using traditional silicon, the raw feedstock that enables the manufacturing of semiconductor chips and conventional solar PV cells. Instead, it is using a promising, yet still unproven, thin-film technology, CIGS, along with novel nanoparticles and patented process technologies. Nanosolar's "photovoltaic ink" can be sprayed or coated onto flexible materials in a continuous-flow process similar to that used by a printing press.

"We're aiming to mass-manufacture solar cells with one hundred times the throughput of conventional cell production, one fifth the cost, and with similar efficiency," explains Nanosolar CEO Martin Roscheisen. "Our goal is to create materials that can be integrated into rooftops and deployed in large-scale ground-mounted plants."

The company has become one of the solar industry's hottest VC plays, lining up more than $100 million in funding. In June 2006 the company announced plans to build a 430-MW-capacity manufacturing line in the San Francisco Bay Area. Roscheisen predicts that Nanosolar's products will be priced competitively with grid-based electricity by 2010. Google cofounders Sergey Brin and Larry Page were early investors in the company, along with such VC stalwarts as Mohr Davidow Ventures and Benchmark Capital, the Sand Hill Road firm that funded eBay and other Internet blockbusters.

Nanosolar's fortunes, along with those of others working in thin-film and nano-based solar technologies, will not be without challenges. No one has yet figured out how to mass-manufacture CIGS technology, for exam-

ple, though many are very close to achieving this feat. Nanosolar's initial products will have warranties in the 15-year range, rather than the silicon-based solar PV industry's average 25-year warranties, and the company's conversion efficiency levels will likely lag behind those of the crystal silicon leaders.

But the move toward "tiny" technology in the solar industry is well under way. Other companies such as Altairnano, DayStar Technologies, HelioVolt, Konarka, Miasolé, and XsunX are developing nano-scale technologies to embed solar PV into everything from rooftops and glass to electronic devices.

The reduction of matter and the integration of nanotechnologies into products could also eventually have a significant impact on the issue of manufacturing waste, with the promise of reducing or even eliminating it. Nanotechnology could be the ultimate goal of a green materials revolution—the replacement of today's "heating, beating, and treating" approach (which not only is materials intensive but also results in significant pollution) with the building of finished materials and products atom by atom. If achieved, this could change the course of modern technology.

BREAKTHROUGH OPPORTUNITY

Utility-Scale Solar

While nanotechnology might enable low-cost solar, the solar-power industry's size and reach will be anything but small. In recent years we've begun to see multimegawatt solar photovoltaics (PV) installations—with some in development as large as 20 MW. And in California's Mojave Desert, there is approximately 300 MW of solar generation provided to utilities from solar thermal concentrators that have been up and running since the 1980s. Combine these larger solar PV and concentrating thermal systems with tens of thousands of smaller distributed PV systems that sit on rooftops, and all of a sudden you have a resource that can be deployed effectively by mainstream utilities in the multimegawatts, especially to provide peak power on sunny, high-demand electricity days. Until recently, most utilities set up roadblocks to the implementation of solar, but that's shifting as government policies, incentives, technology costs, constrained fossil fuel supplies, and other dynamics change. PG&E in Northern California and Austin Energy in

Austin, Texas, are both examples of utilities that are starting to embrace solar power. We believe the embrace of solar by utilities will be one of the big stories in coming years and will provide "utility-size" market opportunities for the solar industry.

THE DEVELOPING WORLD: LIGHTING UP WITH SOLAR

When Nigeria comes up in a conversation about energy, it's usually as an oil-producing nation where political unrest is threatening supplies and helping drive up the price of crude for the entire world. But several hundred miles north of the heavily guarded oil ports near Lagos, in three villages on the desert grasslands of Jigawa State near the Niger border, a very different energy story is unfolding. Here, photovoltaic panels from the Solar Electric Light Fund (SELF) have not only replaced diesel generators and kerosene stoves to provide electricity for basic necessities such as lighting and cooking but are also helping the communities improve and transform. They've brought things that didn't exist before: automated water pumping, free schools with evening adult-education classes and Internet connections, and health clinics with refrigerated vaccines. Perhaps most significantly, they're powering small businesses clustered under one solar roof in micro-enterprise buildings—tailors, barber shops, radio repair, and an oil expeller production shop that crushes peanuts and sells the oil for cooking.

"We've really evolved from simply lighting homes to a village empowerment model, using solar power to enable income generation," says Bob Freling, executive director of SELF, a nonprofit based in Washington, D.C., that finances and manages rural solar projects in Nigeria and 14 other developing countries. Jigawa's governor is looking to expand the model to 30 more villages, and when former president Bill Clinton's Global Initiative development group sought the purchase of carbon offsets to make its 2005 New York City conference "carbon-neutral," it chose the Nigeria project (to the tune of $10,000) for its twin achievements of clean-energy use and increased economic opportunity.

Providing solar energy to rural, off-grid villages in the developing world is a challenging but promising growth opportunity for small entrepre-

neurial companies in the United States and other countries. For more than two decades, Soluz, an innovative company in the Boston suburb of North Chelmsford, Massachusetts, has delivered more than 10,000 clean, distributed electricity systems, usually with solar PV panels, to rural communities in the Dominican Republic and Honduras. Since founder Richard Hansen first flew to Latin America with a solar panel under his arm in 1984, the company has learned that providing clean energy to developing nations requires nothing if not flexibility. "When we started, we used to talk about ourselves as a PV company," says Soluz vice president John Rogers. "Now we use the term REDCO—renewable energy delivery company. It's a proxy for a number of technologies. Customers in these countries aren't motivated by the greenness of it—they just want a high-quality product at a good price."

For Soluz, whose revenue grew 80% in Honduras in 2005, that means providing clean-energy technology on a cash, credit, or lease basis—what Rogers calls "micro-rental." "That makes sense for rural areas," he says. "You can get their costs down to what they'd otherwise pay for kerosene and batteries."

But make no mistake, it's a very challenging business. Lack of infrastructure in remote areas may create the opportunity for off-grid technologies such as solar power, but it also has a major downside. "It's not just a matter of whether the on-site technology can work," says Navigant Consulting managing consultant Shannon Graham. "Is the infrastructure there to support it, in terms of repair, maintenance, parts? I knew of providers in Mexico who would literally fly in to a rural airstrip from Mexico City, drop off and install PV panels, fly out, and never come back. You really have to decide up front if you're doing a development model or a true business model."

One outfit making a pretty good go of it is SELCO India (Solar Electric Light Company). Based in Bangalore, SELCO India operates 25 solar PV sales and service centers serving both rural and urban markets in the states of Karnataka, Kerala, and Andhra Pradesh. Since 1995, SELCO India has installed more than 35,000 solar PV systems, most of them just 50 to 75 W, enough to power three to seven efficient lightbulbs, a radio, and a small TV for a couple of hours. The company is profitable, with yearly revenue of about $3 million. Cofounder and managing director Harish Hande returned to his native country to start SELCO after getting his doctorate in

energy engineering, with a solar power specialty, from the University of Massachusetts Lowell. Hande served as the in-country project manager for the Tsunami Solar Light Fund raised to help rebuild the ravaged infrastructure of Sri Lanka with solar power after the 2004 disaster.

A key part of SELCO's business is helping customers line up financing with partners such as micro-credit provider Grameen Shakti. More than 90% of SELCO's customers use financing with a SELCO partner; the customer typically puts 10% to 25% down and repays a three- to five-year loan at 5% to 14% interest.

Although SELCO's original market was mainly rural, in recent years companies and residents in booming Bangalore have used the company's PV panels for supplemental power because of the area's notoriously unreliable centralized power grid, accounting for some 40% of SELCO's sales. "That's where people have more money, and that helps grow the company so it can do more rural work," says Navigant's Graham.

Exemplifying public–private partnerships, SELCO receives financing from the PV Market Transformation Initiative (PVMTI), a 12-year, $25 million program to seed solar service companies like SELCO in India, Kenya, and Morocco. Administered and funded by the World Bank's International Finance Corporation and the Global Environment Facility, PVMTI focuses on nurturing and growing replicable business models for the selling and servicing of solar PV equipment in those countries.

Throughout rural areas in developing nations, solar and other distributed clean-energy technologies are often the simplest and cheapest electrification option, compared with the expense of building new central power plants, installing a massive grid infrastructure, and running wires from the power grid. Off-grid solar photovoltaic panels are the fastest-growing source of electricity in rural areas of East Africa. Two percent of the rural residents of Kenya use solar power, the highest penetration rate in the world and equal to the rate of rural Kenyans who are connected to the nation's power grid. Nationwide, 20,000 solar home systems are sold annually by more than 50 vendors in Nairobi and some 500 providers in smaller towns. In Brazil, the federal Luz para Todos ("light for all") program aims to electrify 2.5 million rural homes by the end of 2008, 10% of them with clean energy.

The marriage of efficiency and clean energy is particularly critical in remote rural areas. "You can't stop people from wanting TVs and refriger-

ators, but you can make them run better," says Kristin Peterson, cofounder and chief development officer of Inveneo, a San Francisco nonprofit that provides computers with Internet and voice-over-Internet Protocol (VoIP) capability—and the solar PV panels to power them—to villages and schools in Uganda, Afghanistan, and other countries. Inveneo's engineering VP Bob Marsh, who built a computer in the late 1970s that's now in the Smithsonian Institution, developed a computer and communications system that uses only 20 W—one tenth the power of a standard desktop computer and less than half the juice of a laptop. The system usually runs on solar but can also be fired up by a small generator run by villagers or schoolkids taking turns pedaling a stationary bicycle. High tech powered by low tech, if you will, but clean tech nonetheless.

SEEING THE LIGHT

Solar electricity, we believe, will continue to show considerable growth in the years and decades ahead. We expect that silicon-based solar PV technologies will continue to dominate the market for some time, with the advent of nonsilicon and concentrating solar approaches beginning to gain share by the end of the decade. Most important, whether the approach is silicon or nonsilicon, we see a significant scaling up of manufacturing and driving down costs—bringing solar to cost parity with conventional retail electricity in many regions by 2015. We consider solar a shining example of what we call the "semiconductorization of energy"—in which energy technologies are increasingly based on fabrication technologies used in the earlier semiconductor chip revolution. By leveraging many of the same manufacturing techniques used in transistors and chips, solar will see significant cost improvements via economies of scale in production. And like the computer revolution that preceded it, we see significant opportunity for "value-added resellers," or those who integrate, package, and help finance solar systems.

The sector is ripe for change and will be rife with turbulence. There will be mergers, acquisitions, and consolidation in the industry as solar becomes the domain of large, well-funded multinationals and a few stellar newcomers. For every winning start-up there will be dozens of lesser-known failures. But for now, the solar industry provides one of the best opportunities for a Google or Microsoft of the energy sector to emerge.

Continuous cost reductions, manufacturing scalability, technological innovations, and solar's ability to work in a range of embedded applications mean that the solar industry holds bright promise for the future.

THE CLEAN-TECH CONSUMER

Solar mortgage: Increasingly, home buyers will have the option of purchasing a new house with the solar cells already on it, as roof tiles or exterior wall material. Then solar power is embedded not only in the house but in the mortgage as well. That means your electricity cost is part of the home price and mortgage, rather than an add-on expense up front. And if the sun shines enough, monthly electric bills go away too. Says solar industry pioneer Dr. Donald Aitken of the Union of Concerned Scientists: "Why should you own your home but rent your electricity?" His idea could catch on. With programs like California's 2006 Million Solar Roofs initiative offering $3 billion in rebates and incentives over 11 years, BIPV will be a common feature of new home construction.

Mighty fine lighting: How about a solar-powered lantern that costs around 45 bucks and lasts up to 30 years? Dubbed "the new electric lamp" by *Time* magazine in 2006, the MightyLight from U.S.–India joint venture Cosmos Ignite Innovations is just that. It has replaced polluting, dangerous, and nonrenewable fuel–burning kerosene lamps for thousands of people in India, Pakistan, Afghanistan, Guatemala, and Rwanda. The key component is the most efficient lighting technology on the market, the solid-state light-emitting diode (LED). Cosmos Ignite focuses on poor, needy areas with both direct sales and grant-funded distribution, but anyone can order a MightyLight online.

TEN TO WATCH

Applied Materials

Santa Clara, California
www.appliedmaterials.com
NASDAQ: AMAT

What's Applied Materials, the leading equipment manufacturer in the semiconductor industry, doing in solar? In late 2006 the company announced plans to enter the solar industry. As part of its activities, the company acquired Applied Films, a firm that, among other things, has a thin-film solar manufacturing equipment business. Charlie Gay, a solar industry veteran most recently at SunPower, was recently brought on to help guide Applied Materials in its solar ramp-up—and the company's venture arm has begun investing in a number of clean-energy concerns, including silicon wafer manufacturer Solaicx. As the solar industry expands, Applied Materials is positioning itself to do for solar what it did for the computer industry.

Miasolé

Santa Clara, California
www.miasolé.com

The founders of Miasolé initially developed their technology for a very different market: disk storage. Now they're applying their "sputtering" technology to develop low-cost, high-efficient solar cells. With funding from the likes of Netscape and Yahoo backer Kleiner Perkins, Miasolé is in a strong position to take lessons learned from the high-tech industry and apply them to clean tech.

MMA Renewable Ventures

San Francisco, California
www.mmarenewableventures.com

The solar power industry is full of technology innovators. MMA, like another company on this list, SunEdison, stands out for its innovations in project finance. Once a VC firm, MMA decided to invest in on-site solar

PV projects instead of companies. For clients ranging from a museum in Bridgeport, Connecticut, to a Napa Valley winery, MMA builds an on-site PV system with third-party investor financing and sells the electricity to the client in a power purchase agreement. MMA raised a $100 million fund from institutional investors in 2006 to finance such projects. Formerly Renewable Ventures, the company added MMA to its name after its 2006 acquisition by real estate financier Municipal Mortgage & Equity LLC (NYSE: MMA), better known as MuniMae.

Nanosolar

Palo Alto, California
www.nanosolar.com

In mid-2006 Nanosolar announced plans to develop a 430-MW solar production facility in the San Francisco Bay Area—based on a new form of nanotechnology that basically lets you "print" solar cells. It's audacious by any standards, considering that Sharp took more than 30 years to reach the 400-MW milestone and that the second-largest solar PV manufacturer, Q-Cells, took about 6 years to reach 200-MW production capacity. But the company has some big backers and a unique technology platform, so it could potentially deliver on a next-generation solar solution.

Q-Cells

Thalheim, Germany
www.q-cells.com
Munich Stock Exchange: QCE

The German solar cell manufacturer raised nearly $300 million in its 2005 IPO and was the ninth-fastest growing company in Europe that year. Q-Cells is helping drive down costs of traditional crystalline silicon cells with large-scale manufacturing improvements and greater generating efficiencies from the cells themselves.

REC
Høvik, Norway
www.scanwafer.com
Oslo Stock Exchange: REC.OL

A diversified solar company, REC does everything from solar-grade silicon production to wafer, cell, and module manufacturing. It operates three groups, REC Silicon, REC Wafer, and REC Solar. The company went public on the Oslo Stock Exchange in 2006 and is well positioned because of its diversified approach. While others scramble to gain access to silicon feedstock in a constrained environment, REC can rely on its own supply. It also provides silicon to the largest solar player in the world, Sharp; the company recently signed a deal worth nearly U.S. $500 million through 2012 to supply silicon to the company.

Sharp
Osaka, Japan
www.sharp.co.jp
Tokyo Stock Exchange: 6753

The granddaddy of solar, Sharp currently dominates the global solar market. It not only pumps out around 25% of total worldwide solar cell and module supply but also commands an impressive lead in the growing U.S. market. Sharp will have to fight to stay ahead as the market transforms, but we see it staying a dominant force in the industry. What other multinational's president is stating that solar could generate up to 20% of his firm's total revenue by 2010?

SunEdison
Baltimore, Maryland
www.sunedison.com

An innovative player in solar systems packaging and finance, SunEdison seems to be making all the right moves. It received $60 million in funds from a number of banks, including Goldman Sachs, in 2005. It has been on a buying spree acquiring installation and systems integration capabilities. We believe others are likely to replicate and improve on SunEdison's

model, so the company must figure out how to stay ahead of the curve. But for now, SunEdison is impressive for developing a unique model and delivering on its strategy.

SunPower

Sunnyvale, California
www.sunpowercorp.com
NASDAQ: SPWR

Acquired by chip industry pioneer Cypress Semiconductor in 2002 and then spun off in a successful IPO in 2005, SunPower is emerging as a leading player in low-cost, high-volume solar cell production. Its Manila manufacturing facility currently produces 25 MW of solar panels yearly, with the capability to expand to 100 MW; $50 million from its IPO cash haul should help. Industry watchers have hailed SunPower's $332.5 million acquisition of top solar project developer PowerLight as a strong combination.

Suntech Power

Wuxi, Jiangsu Province, China
www.suntech-power.com
New York Stock Exchange: STP

China could very well be the next big solar market, following in the footsteps of Japan, Germany, and California. Chinese manufacturers such as Suntech Power, who are known for driving down manufacturing costs, won't only ship their wares abroad but will also provide cells, modules, and services to the millions of people without access to reliable grid electricity in China. Suntech Power, which was the first major Chinese solar company to go public on a U.S. exchange, is well positioned to reap the benefits of a growing domestic and international market for its products.