SOLAR POWER MARKETS BOOM

The energy companies of the future are shouting the news of renewable energy from the rooftops.

by Christopher Flavin and Molly O'Meara

In June 1998, Oguz Capan, president of Turkey's ROC Oil Company, visited the Worldwatch Institute's offices in Washington. The purpose of his visit was surprising: low oil prices and a slow market had persuaded him to sell his small petroleum production business and invest the proceeds in wind and solar energy, enterprises that hardly exist in Turkey today. But Capan was optimistic. These new energy sources, he told us, will be far more profitable than oil. He wanted to know what we could tell him about how the new technologies are performing around the world.

Capan's timing may be propitious, because recent developments may soon allow solar energy to join computer software and biotechnology as a leading growth industry.[1] Last year, sales of solar photovoltaic (PV) cells expanded 42 percent, a rate of growth that would be more familiar to Microsoft or Sun than to Exxon or Shell (see Figure 1).

That spurt gave the solar industry a fourth straight year of double-digit growth. "We are seeing PV change from a cottage industry into a profitable business worldwide," says Ken Zweibel of the U.S. National Renewable Energy Laboratory (NREL). "Today, you can sell anything that you can make." By "anything," Zweibel is referring to the small silicon cells that form the technical basis of this business, and for which suppliers this year are having to scramble to keep up with demand.

Touted for more than two decades as an eventual replacement for fossil fuels, solar power has—until now—failed to make the commercial leaps needed to challenge conventional energy technologies. Made of silicon semiconductors closely related to those found in computers (much of the silicon used for solar cells is actually waste from the electronics industry), solar cells are one of the newest and most advanced energy technologies in use today.

Invented in the 1950s, and first deployed in the U.S. space program, solar cells accomplish a feat of near-alchemy—turning solar rays directly into electric current, without benefit of fuel, mechanical turbine, or generator. As early as 1957, *Business Week* was rhapsodizing about the potential of solar power, envisioning a solar car in which "riders sit comfortably in the back seat and perhaps watch solar-powered TV." Although solar power has a long way to go to overtake fossil fuels, thousands of people already have

[1] Wind energy, too, is growing fast; its total capacity worldwide has increased at a rate of 25.7 percent annually since 1990. During the same period, solar capacity has increased at a rate of 16.8 percent per year (see "Wind Power Sets Records" in *Vital Signs 1998*, Worldwatch Institute, 1998).

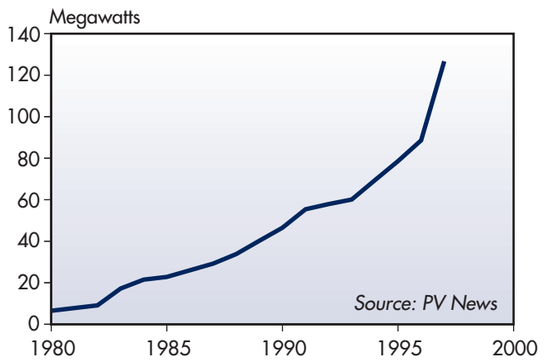


Figure 1: World Photovoltaic Shipments, 1980–97

solar powered TVs and thousands of others have solar cells built into the sunroofs of their cars—powering fans that keep them cool.

Roughly half of the world market for PVs last year was in non-residential applications such as portable highway signals, radios, telecommunications repeater stations, and water pumps, where the only alternatives are high-cost diesel generators. Another 20 percent is used in small consumer devices such as calculators and watches. Unlike most energy technologies, photovoltaics are lightweight, modular, and can be used economically in such devices.

The current boom in solar energy is being driven by a previously neglected small-scale application: providing power for individual houses one at a time, which accounts for most of the remaining 30 percent of the market. From tiny huts in rural areas of the Dominican Republic to trim suburban homes in Osaka, Japan, some 500,000 homeowners are now generating their own power.

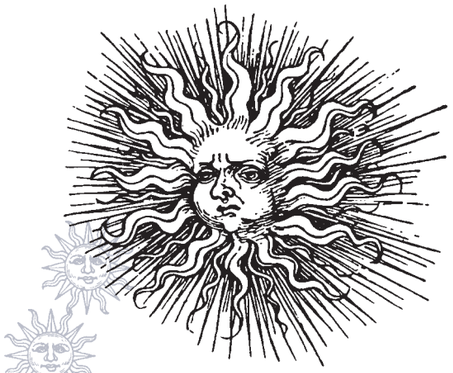
Since 1980, the price of solar cells has fallen by 80 percent, as the technology has matured (see Figure 2). In the past decade, the industry's advance has slowed, however, due to low oil prices, a lack of sufficient government support in many countries, and a reluctance of manufacturers to commit the resources needed to bring down costs. As a result, prices have temporarily stabilized—and while last year's sales surged, the market's expansion over the past decade has averaged only about 16 percent per year.

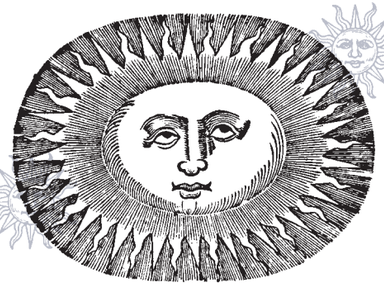
The potential, however, is much larger. For the 2 billion people in the world who are still not connected to power lines, solar cells are often the least expensive means of meeting their needs for lights, radio, or even television. The World Bank, for example, has a program to install solar systems for 200,000 households in Indonesia, and similar efforts are underway in many other developing countries. And even many people in the industrial world are not connected to the grid. John Thornton, who works at NREL's Golden, Colorado lab, has seen solar homes grow in popularity in the Rocky Mountains. At $20,000 for a modest system that includes a battery to store the power for night-time use, they are a bargain compared to the $50,000 to $75,000 the local utility charges to extend power lines to a new home that is just one mile from the grid.

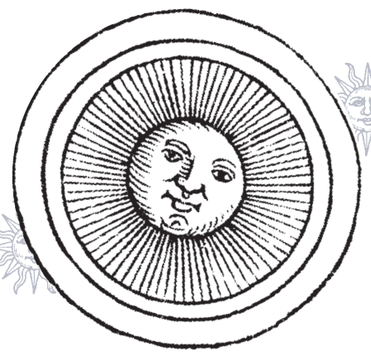
For the roughly 4 billion people in the world who are already connected to electric lines, solar power systems still cost two to five times as much as providing power from the grid. However, technological advances are rapidly lowering that ratio.

One such advance is the integration of solar cells into roofing shingles, tiles, and even window glass—turning standard building materials into nearly invisible power generators. In some areas, home buyers can now choose the option of a solar-powered home connected to the grid, which would meet most of their electricity needs for 30 years. It would add about $100 per month to the mortgage of a $200,000 house, while reducing power bills by roughly half that amount.

Government support for solar home systems—led by the government of Japan, which provides generous subsidies for rooftop solar power—has triggered the current solar boom. Japan requires electric utilities to purchase electricity produced by these systems at the same price they charge consumers—a price that is currently more than 20 cents per kilowatt-hour. The transaction is determined by "net metering," meaning that the rooftop's output is subtracted from the consumer's use of power from the grid. At the end of the month, the consumer pays a utility bill that covers the "net" electricity used. Some 9,400 solar home systems were installed under this arrangement in 1997, and 13,800 are expected in 1998. Japanese officials say they hope to have solar power systems in 70,000 homes by 2000, and to be able to eliminate direct subsidies by the year after that, as the market continues to grow.







Europe and the United States, too, have launched ambitious new solar power programs. Each has announced a "Million Roofs" initiative designed to dramatically boost the size of their domestic markets. Neither has yet been fully formulated, but both have already spurred private companies to invest. The U.S. plan includes several proposed federal policy changes, including a tax credit for 15 percent of the cost of a new system. It will also rely on partnerships with electric utilities, non-profit organizations, and state and local governments to fulfill its aims. One key to making this program successful is to encourage widespread net metering, as is already happening in Japan, Switzerland, and half of the U.S. states.

In Sacramento, California, the locally owned utility has shown the way with its PV Pioneers Program, launched in 1993. Already, some 420 homeowners pay $4 per month to keep a 3- to 4-kilowatt solar panel on each of their roofs. As in Japan, these individual panels feed power into the local utility grid. (The utility pays for the initial installation—typically $20,000 per home.) Since the program began, the cost of the systems has steadily declined. To ensure further progress, a long-term contract was recently signed with a solar manufacturing company to begin producing cells locally. By 2002, the fully installed cost of one of these systems is projected to fall by half, to below $3,000 per kilowatt. That would provide power for roughly 9 cents a kilowatt-hour, which is competitive with the cost of providing power at times of peak demand.

The success of Europe's Million Roofs Program, which is equally divided between domestic installations and planned exports to developing countries, will depend on new European Union initiatives yet to be announced, and on policies enacted by the 17 member states of the E.U.—possibly building on pro-

grams already in place in several nations. In Germany, some 3,500 homeowners now have solar power, thanks to government subsidies and a high utility purchase price for the extra power. Taking advantage of the construction boom underway in Berlin, the German government has also built PVs into the new Parliament Building, Ministry of Economics, and Main Railway Station. Switzerland now has more solar power installed per person than any other country, including rooftop systems for 170 public schools, and has recently offered purchasers of PV systems a subsidy of up to 25 percent of the up-front cost.

One of the advantages of these kinds of solar power systems is that they are located near the customer and can enhance the overall reliability of power supplies. This is useful because the world's electric grid systems are heavily dependent on large power plants and long transmission lines, which makes them vulnerable to various kinds of breakdown.

In recent months, waves of hot weather and a power grid debilitated by the shutdowns of nuclear plants led to a spate of brownouts in the U.S. Midwest and Northeast. Utilities had to scramble for power, and in some cases were forced to purchase it from distant markets for over 100 times the usual price. Martin Cohen, Executive Director of the Illinois Citizens Utility Board, told the *Chicago Tribune*: "It used to be that the only power outages we had to worry about were the ones when aging infrastructure failed. Now we have a new vulnerability to outages in distant locations, transmission lines going down, or trouble at power plants far away." Solar cells, on the other hand, have no moving parts, and are at their most productive on hot summer afternoons when power demand is at its peak.

The restructuring of electric power markets, now underway around the world, may open up new ways to sell solar electricity. For instance, in New England, a newly formed electric company, Sun Power Electric, plans to mount solar panels on the numerous flat roofs owned by a large chain of retail stores. Electricity not used by the stores will be sold to other local consumers by way of a "green power" marketer. Sun Power president Steve Cowell says he thinks mass-production and assembly of the panels will bring down the cost of PV-generated power, so that it will be cost-effective within 10 years.

Market growth, combined with the spur of international efforts to slow climate change, has made solar power a hot field for profit-minded investors in the past two years. At least 8 companies that draw more than 20 percent of their business from PVs are now publicly traded, according to PV industry analyst Paul Maycock. Several major companies, such as Canon, Honda, and Siemens, have also invested in solar power. And the U.S. energy firms Enron and Amoco have teamed up to increase investment in their jointly owned Solarex Company—most recently with a $7.7 million three-fold expansion of their solar cell plant in Maryland.

In breaking with most of the rest of the oil industry on climate change policy last year, British Petroleum CEO John Brown said that his company would expand its investments in solar energy, boosting its sales tenfold over the next decade—to $1 billion. And Royal Dutch Shell has formed a fifth core corporate group that plans to invest $500 million in renewable energy over five years. Of course, such numbers look small compared to these companies' other investments. Shell's expenditures on its new solar initiative, for instance, will be only 5 percent of what it spends annually on its fossil fuel production, processing, and marketing businesses. However, given the small base from which the PV industry is building, those announcements provide an important boost. The BP goal alone, for example, is equal to the PV industry's total world sales in 1997.

These companies and others are investing in new solar manufacturing plants—factories that are expected to further reduce the cost of solar power by deploying the latest technology and increasing the scale of production. Royal Dutch Shell, for example, has teamed with Pilkington Solar International to build a 25-megawatt factory in Germany, the world's largest so far—at least until planned expansions by companies such as Kyocera in Japan and Photowatt in France are completed.

One way these large plants are increasing efficiency is through automation. The silicon in solar cells typically accounts for only 10 percent of a module's cost, leaving ample room for streamlined assembly to reduce costs. And as companies scale up production, robotics will become more cost-effective. For several years, with producers racing to keep up with rising demand, the average price for PVs has remained at around $4,000 per kilowatt. However, according to the Massachusetts-based Spire Corporation, which makes equipment for manufacturing solar modules, its latest equipment allows large factories to produce modules at $1,780 per kilowatt and potentially sell them for as low as $2,000 per kilowatt.

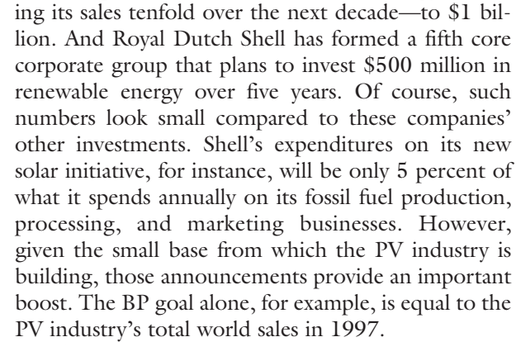


Figure 2: Average Factory Price for Photovoltaic Modules, 1980–97

Also on the horizon are potential gains in the efficiency of the solar cells themselves. Single crystal cells, the mainstay of the industry for four decades, still accounted for nearly half of sales in 1997. Another 34 percent consisted of the newer polycrystalline cells, which are a bit less efficient but also cheaper to produce. Researchers continue to investigate ways to bring down the major cost of these crystalline technologies, which entail growing silicon crystals and slicing them into solar cells. For instance, one polycrystalline technology being developed by the company ASE Americas reduces material and energy input by growing the silicon in long "ribbons" that are then cut into cells with lasers.

The other main class of solar cells in use today is the non-crystalline "thin film" cells that are less than one one-hundredth of the thickness of conventional solar cells. They do not need to be sliced or rigidly encased, and can be made into large, flexible sheets ideal for integrating into building materials such as shingles. These thin films are less efficient than crystalline technologies, but they are much cheaper. They also use less raw material, so costs are cut further. Employing the new technologies, companies such as United Solar, Solarex, and Canon have recently expanded their annual thin film production capacity by 5 to10 megawatts. The goal of researchers at the U.S. National Renewable Energy Laboratory is to develop a thin film cell that slashes the installed cost of solar cells to a point where they can compete even in the highly competitive bulk power market.

Though still tiny by energy industry standards, the solar market has recently grown at 10 times the rate of world oil production. If annual production were to grow at 25 percent per year through 2020, solar capacity would reach 106,000 megawatts by 2020, generating as much power as 30 to 40 large nuclear plants. In Sacramento, the local utility estimates that the city could generate 400 megawatts of electricity, one-sixth of the local peak demand, simply by covering the available south- to west-oriented roofs, parking lots and transmission-line corridors with solar panels.

At a broader level, researchers at the U.S. Department of Energy estimate that if PV panels were mounted atop 5,000 square kilometers of roof space, they could generate 25-percent of the electricity used in the United States. And a study by Shell projects that solar and other renewable energy sources could grow from less than 1 percent of world energy use today to 5 to 10 percent by 2020 and 50 percent by mid-century.

The world still has a long way to go if the energy system is to be effectively "de-carbonized" over the next century, as most atmospheric scientists believe it must. Solar energy cannot do the job alone, but combined with other new technologies such as wind turbines and hydrogen fuel cells, as well as more resource-conserving urban designs, products, processes, and lifestyles, it may allow the world to live a little cooler in the twenty-first century.

LEADING PV PRODUCERS, 1997

The top 5 accounted for 60 percent of PV shipments in 1997.

Company	Country	Megawatts Shipped in 1997
1. Siemens Solar	United States*	24.0
2. Kyocera	Japan	15.4
3. Solarex	United States	14.8
4. BP Solar International	United Kingdom	11.3
5. Sharp	Japan	10.6

*Siemens is a German-owned company, but most of its production is in the United States.

SOURCE: Maycock, *PV News*, February 1998.

Christopher Flavin is senior vice president of Worldwatch Institute and Molly O'Meara is a staff researcher at the institute. Flavin is co-author of *Power Surge: Guide to the Coming Energy Revolution* (W.W. Norton, 1994).