How sunlight became a commodity in Germany

Philip Ball

If you had to guess which country produces the most electrical power from photovoltaics (PV), you would probably draw candidates from sunny places such as the Middle East, the Mediterranean, or the United States. Germany, with its gray northern European skies, seems an unlikely contender. But there it is: between one-third and one-half of the PV power in the world flows in Germany, amounting to a little more than six gigawatts.

This is the result of deliberate policies to encourage the uptake of solar energy, ranging from support for fundamental research to schemes that guarantee competitive pricing for electricity from renewable sources. According to Anton Milner, former CEO of the PV manufacturer Q-Cells, the German government has provided tens of billions of euros to stimulate the spread of PV, an initiative that he calls an "unmitigated success."

The proportion of Germany's energy generated by PV might sound small—about 1–2%—but it represents a significant fraction of the total contribution (14%) from renewables, and the market is growing exponentially. This, in turn, drives costs down, and the solar-power industry also has created around 50,000 jobs in Germany and brought revenues of €5.6 billion ($6.9 bn) in 2009. Famously committed to green issues, Germany has set an ambitious CO_2 emission-reduction target of 40% by 2020, relative to the 1990 level, and PV will be a major player in that strategy. According to Karsten Körnig, managing director of the German Solar Industry Association (BSW-Solar), it is hoped that 5–10% of German energy will be solar by 2020.

Perhaps the biggest stimulus for PV was the German government's Renewable Energy Sources Act, framed in 2000 and significantly amended in 2004 and 2008. Anyone in Germany now has the right to produce electricity through PV and feed it into the grid, forcing an open market. But the most significant aspect of the Act was the provision of a so-called feed-in tariff for renewable energy. This allows producers to sell their electricity to utilities companies at a guaranteed price over a 20-year period, which is considerably greater than the normal "grid" rate. The tariff scheme actually began in 1990, but only after 2000 did it become favorable for PV, which tends to be more costly than other renewables such as wind, by adjusting the pricing to allow for the different costs of generation. This kind of price security, said Milner, "creates investment in and a market for PV—it forces the development of the industry."

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"Driving costs downwards is the key," said Bernhard Beck, CEO of the German PV company Beck Energy. Currently, he said, there is a 5–10% cost reduction in solar electricity every year, largely because of the efficiencies that come from the increasing scale of the industry. Since 2002, Beck's company has installed more than 75 large-scale solar power plants, primarily in Europe, which typically produce 15 MW of electrical power. But most of the PV systems in Germany are smaller: about half are commercial rooftop systems producing 10–1000 kW, and most of the remainder are small domestic-scale roof panels (1–10 kW).

Research and development also has been pivotal to the industry's growth. While Beck said that much of the academic research on fundamental aspects of semiconductor optical behavior remains remote from applications, improvements in the performance and processing of the two main commercial technologies—silicon wafer and thin-film cells—have been crucial.

"There were no thin-film devices when I started in this business," said Milner. "Now cadmium telluride thin films are the second largest PV material system out there."

Thin-film devices are made by depositing a semiconductor, typically CdTe, onto a substrate, a technique pioneered by the U.S. company First Solar, now globally the largest manufacturer of thin-film cells. The efficiencies of these devices are typically lower than those of crystalline silicon (around 9% in commercial modules), but the processing and production costs are lower. They may drop still further as other producers, particularly in China, enter the market.

All of First Solar's modules are recycled—cadmium, tellurium, and glass—with the cost being met at the time of sale. That money is held in a bank so that it is still there if the company goes bust. However, in the long term, tellurium is a scarce element, and there are questions about whether it might become too expensive in the future.

"We think not," said David Eaglesham, First Solar's CTO. "But if we are wrong, then eventually another technology will displace us"—a confidence that undoubtedly relies on the ingenuity of materials scientists.

Other thin-film materials are also improving. The Center for Solar Energy and Hydrogen Research (ZSW) in Stuttgart has recently claimed a record 20.1% efficiency for thin-film cells made from copper, indium, gallium, and selenium (CIGS). CIGS cells are already commercially available (from Q-Cells, among others) and have the advantage of being free from toxic cadmium.

Improvements in silicon cells have been more incremental but steady, for example, reductions in wafer thickness—currently

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silicon films in commercial devices are around 200 μm thick, but researchers hope to cut that in half. Other types of semiconductors, such as the III–V materials, can achieve higher efficiencies but are still very expensive—although they find a niche market in satellite technology, where lightness is more important than unit cost. The best efficiencies are achieved in complex devices that use multilayers of III–V thin films. A team at the Fraunhofer Institute for Solar Energy in Freiburg, led by Eicke Weber, last year claimed a record efficiency of 41.1% in one of these "multiple-junction" solar cells, in work that benefited from the German funding initiative.

The Fraunhofer Institute is one of many PV research centers and manufacturers (including Q-Cells) in the so-called Solar Valley in eastern Germany that grew out of the massive investment in the semiconductor and chemical industries in this region after reunification. Fully 65% of PV cell production in Germany now comes from this area, encompassing the states of Saxony, Thuringia, and Saxony-Anhalt.

For PV technology to really make a difference, there is plenty of scaling up that still needs to be done. "If we are going to be successful at tackling the global warming challenge, then we have barely begun," said Eaglesham. "There are also challenges in permitting large construction projects and in managing the grid with this much renewable energy on it." But he adds that "the real scaling issues are societal and governmental: Can we encourage adoption of PV at this level?"

But it is not just about research; the PV market has to be actively encouraged.

What can other countries learn from the German example? The 46 Energy Frontier Research Centers launched last August as part of U.S. President Obama's initiative on new energy technologies include several institutions that will focus on PV, for example at the California Institute of Technology, Northwestern University, and the University of North Carolina. But it is not just about research; the PV market has to be actively encouraged. Here, what one might call the positive discrimination of the German government has been central. "The feed-in tariff was what got it started," said Eaglesham, whose First Solar has just announced a second factory in Germany. "It's brought the industry to scale, has delivered enormous cost reductions for the technology, and brought the industry to a point where PV is affordable. We need the rest of the world to pick up where Germany has started."

But Beck said that such support must be sustained and reliable. The feed-in tariff rate will soon be reduced—something that was always planned, and which the government insists is needed to maintain competitiveness, but which has brought protest from PV manufacturers. And Beck points out that lobbying by nuclear and coal interests has induced the government to rescind on some commitments, for example refusing to support PV plants on former agricultural land. "The tariff system is exactly the right way to go," he said, "but it mustn't suffer too many changes. Companies need to be able to trust it. So PV needs to build up a strong lobby group." □

A 1.45 MW solar power plant at Dimbach in Germany, which uses CdTe thin-film cells and was constructed in 2003–2004 by Beck Energy GmbH. Courtesy of Beck Energy GmbH.

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