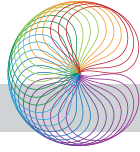
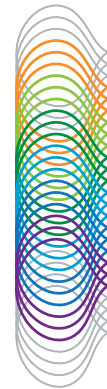


innovation



The Spectrum of
Clean Energy Innovation



Fundamental Science
Market-Relevant Research
Systems Integration
Testing and Validation
Commercialization
Deployment

Rapid Deposition Technology Holds the Key for World's Largest Solar Manufacturer

In a long-term collaboration with the National Renewable Energy Laboratory (NREL), an innovator in thin-film solar technology has grown from a start-up company to become the world's largest manufacturer of solar modules. First Solar, Inc. now manufactures its cadmium telluride (CdTe) solar modules throughout the world, and in 2009, it became the first solar manufacturer in the world to produce more than 1,000 megawatts (MW) of solar panels in a single year. That's enough solar modules to equal the generating capacity of an average-sized nuclear power plant.

Most solar cells and panels sold throughout the world depend on silicon semiconductors to work their magic. But researchers at NREL and at the U.S. Department of Energy have long known that large-scale, cost-competitive deployment of solar power requires the use of less-expensive materials.

A key solution to this problem, which NREL has pursued for decades, is the thin-film solar module, which employs thin films of semiconducting material applied to a substrate such as glass, metal, or plastic. Such devices use only a small fraction of the semiconductor materials used in conventional silicon solar cells, potentially yielding significant cost savings. NREL's success in spurring the thin-film solar industry is demonstrated by First Solar, which is now the world's largest solar manufacturer.

Through deep technical expertise and an unmatched breadth of capabilities, NREL leads an integrated approach across the spectrum of renewable energy innovation. From scientific discovery to accelerating market deployment, NREL works in partnership with private industry to drive the transformation of our nation's energy systems.

This case study illustrates NREL's innovations and contributions in Market-Relevant Research through Commercialization.



PIX 08730

First Solar, Inc. is NREL's biggest success to date with the manufacture of thin-film solar modules. Courtesy of First Solar

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL started working with First Solar's predecessor, Solar Cells, Inc., in 1991, when the company was located on the campus of the University of Toledo in Ohio. Solar Cells was focused on depositing CdTe on glass, forming rigid solar modules similar in appearance to traditional solar modules made from crystalline silicon solar cells.

Solar Cells kept making steady progress and eventually started a pilot line with a capacity of about 2–3 MW. In 1999, private investors formed First Solar, Inc. as a joint venture with Solar Cells, and later bought out Solar Cells' stake in the company. In its early years, First Solar developed a range of novel technologies to make it easier to manufacture its thin-film-on-glass solar modules. Along the way, the company continued to collaborate with NREL.

A key innovation developed through this collaboration is a technology known as High-Rate Vapor Transport Deposition (HRVTD), in which the material to be deposited is carried on a gas stream in powder form, then heated and vaporized as it passes through a membrane before depositing on the glass substrate. This deceptively simple technology can deposit a thin, uniform layer of CdTe or cadmium sulfide (CdS) on 8 square feet of glass in less than 40 seconds—a deposition rate 3–4 orders of magnitude greater than rival thin-film solar technologies. The technology was the key to success for First Solar's first production line, which was able to crank out one solar module per minute.

First Solar's first production line was located at a plant in Perrysburg, Ohio, and it incorporated the HRVTD technology in 2003, where it continues to be used today. The production line feeds soda lime glass into vacuum deposition chambers where the HRVTD process is used to deposit first a layer of CdS, then a layer of CdTe. The modules are then scribed with a high-speed laser, metal contacts are added, and the thin-film structures are encapsulated in ethyl vinyl acetate. To finish the module, wires and another protective layer of soda lime glass are added, and the module is framed in aluminum.

"NREL expertise played a key role in helping First Solar get established in its early days," says David Eaglesham, vice president of technology at First Solar. "NREL plays a very crucial role for the photovoltaic community in the United States and provides invaluable expertise and learning for companies getting started in this business."

The Perrysburg facility eventually expanded to four production lines. First Solar continues to perfect its production process, and today, the company pushes about 59 MW of solar modules per year through each of its production lines, for a total U.S. production capacity of 236 MW. The company has also improved the conversion efficiency of its solar modules to 11.2%, which means that more than one-tenth of the sunlight hitting the module is converted into electricity. First Solar has also cut its direct manufacturing costs from more than \$3 per watt in 2004 to only \$0.76 per watt today.

First Solar now operates a manufacturing plant in Germany with four production lines, as well as four new manufacturing plants in Malaysia, each one featuring four production lines, for a worldwide total of 24 production lines. With those new plants operating, the company's total production capacity equals nearly 1,400 MW per year, making it the world's largest solar manufacturer.

First Solar is also continuing to expand, despite lingering economic woes in many parts of the world. The company is planning to add 14 more production lines in France, Germany, and Malaysia, which means First Solar will have 38 production lines operating throughout the world by early 2012. Based on today's annual production rate of 59 MW per production line, the new facilities will bring the company's annual production capacity to more than 2,200 MW.

First Solar Timeline

- 1986 Dr. Harold McMaster founds Solar Cells, Inc. in Toledo, Ohio.
- 1991 NREL begins its collaboration and support for Solar Cells.
- 1999 Private investors start First Solar, Inc. as a joint venture with Solar Cells.
- 2003 First Solar's Perrysburg, Ohio, manufacturing plant incorporates the HRVTD process, which allows for the mass production of solar modules.
- 2004 First Solar achieves full commercial operation of its Perrysburg plant, producing 20 MW per year at a cost of more than \$3 per watt.
- 2006 First Solar adds two more production lines to the Perrysburg plant, boosting annual production capacity to 75 MW.
- 2007 First Solar opens four production lines at a new plant in Germany.
- 2008 First Solar opens eight production lines in Malaysia, more than doubling its production capacity. The company reaches a total production of 500 MW and reduces its manufacturing cost to less than \$1 per watt. It also boosts production at each manufacturing line to 48 MW per year, increasing its annual production capacity to 528 MW.
- 2009 First Solar reaches a total production of 1,000 MW in March, then achieves an annual production of 1,000 MW by year-end. The growth is aided by eight more production lines in Malaysia and an increase in production at each line to 53.4 MW per year.
- 2010 Production at each manufacturing line reaches 59 MW per year, while manufacturing costs drop to \$0.76 per watt. A fourth production line is added in Perrysburg, increasing annual production capacity to more than 1,400 MW.

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401
303-275-3000 • www.nrel.gov

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

NREL/FS-6A42-48861 • October 2010

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 10% post consumer waste.