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Summary

Every President since Richard Nixon has sought to increase U.S. energy supply diversity. Job creation and the development of a domestic renewable energy manufacturing base have joined national security and environmental concerns as reasons for promoting the manufacturing of solar power equipment in the United States. The federal government maintains a variety of tax credits and targeted research and development programs to encourage the solar manufacturing sector, and state-level mandates that utilities obtain specified percentages of their electricity from renewable sources have bolstered demand for large solar projects.

The most widely used solar technology involves photovoltaic (PV) solar modules, which draw on semiconducting materials to convert sunlight into electricity. By year-end 2013, the total number of grid-connected PV systems nationwide reached more than 445,000. Domestic demand is met both by imports and by about 75 U.S. manufacturing facilities employing upwards of 30,000 U.S. workers in 2014. Production is clustered in a few states including California, Ohio, Oregon, Texas, and Washington.

Domestic PV manufacturers operate in a dynamic, volatile, and highly competitive global market now dominated by Chinese and Taiwanese companies. China alone accounted for nearly 70% of total solar module production in 2013. Some PV manufacturers have expanded their operations beyond China to places like Malaysia, the Philippines, and Mexico. Overcapacity has led to a precipitous decline in module prices, which have fallen 65%-70% since 2009, causing significant hardship for many American manufacturers. Some PV manufacturers have closed their U.S. operations, some have entered bankruptcy, and others are reassessing their business models. Although hundreds of small companies are engaged in PV-related manufacturing around the world, profitability concerns appear to be driving consolidation, with fewer than a dozen firms now controlling half of global module production.

In 2012, the United States imposed significant dumping and countervailing duties on imports of Chinese solar products after ruling that U.S. producers had been injured by dumped and subsidized solar equipment from China. In a second case, the U.S. Department of Commerce (DOC) and the U.S. International Trade Commission (ITC) ruled in 2014 and early 2015 that U.S. producers were being injured by imports of Chinese-made modules that avoided the duties imposed in 2012 by incorporating solar cells from Taiwan. While these duties may help U.S. production become more competitive with imports, the cost of installing solar systems might rise. Domestic demand for solar products may also be depressed by the end of various federal incentives. Unless extended, the commercial Investment Tax Credit for PV systems will revert to 10% from its current 30% rate after 2016, while the 30% credit for residential investments will expire.

Looking ahead, the competitiveness of solar PV as a source of electric generation in the United States will likely be adversely affected by the rapid development of shale gas, which has lowered the cost of gas-fired power generation and made it harder for solar to compete as an energy source for utilities. In light of these developments, the ability to sustain a significant U.S. production base for PV equipment is in question.
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Introduction

Major developments affecting the domestic photovoltaic (PV) manufacturing sector include technological advances, improved production methods, dramatically lower prices for PV modules, and trade frictions, particularly with China. These volatile industry trends have adversely affected the operations of many solar companies, forcing some to reassess their business models and others to close factories or declare bankruptcy. In addition, the rapid growth in shale gas production has the potential to affect the competitiveness of solar power, as cheap natural gas possibly may provide an alternative source of energy at a lower price. If oil and gas prices stay low, demand for renewable energy, including solar, might be hurt. These trends affect the ability of the United States to build a sustained domestic production base for PV equipment.

U.S. solar manufacturing makes up a small part of the U.S. manufacturing base. In 2014, the nation’s solar manufacturing industry directly employed about 32,000 workers, according to the Solar Energy Industries Association (SEIA), a trade group. The U.S. cell and module market, measured by domestic shipment revenues, has grown in size from $3.3 billion in 2008 to $7.1 billion in 2012, reports the U.S. Energy Information Administration (EIA). Following an unprecedented period of growth, the number of PV systems in the United States reached more than 445,000 by the end of 2013, more than twice the total at the end of 2011.

Government support has been instrumental in sustaining the solar industry worldwide. In the United States, tax incentives and stimulus funding have helped to spur new PV installations. In its 2013 annual report, SEIA wrote that “more solar has been installed in the United States in the last eighteen months than in the 30 years prior.” Nevertheless, even

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A PV Glossary

PV stands for photovoltaic, a term derived from “photo” for light and “voltaic” for a volt, a unit of electrical force.

*Solar photovoltaic*, or solar PV, is a technology that uses the basic properties of semiconductor materials to transform solar energy into electrical power.

A *solar PV cell* is an electricity-producing device made of semiconducting materials. Cells come in many sizes and shapes. Materials used to make cells include monocrystalline silicon, polycrystalline silicon, amorphous silicon (a-Si), cadmium telluride (CdTe), copper indium gallium (di)selenide (CIGS), and copper indium (di)selenide (CulnSe2 or CIS).

*Panels, or modules*, are assembled from a number of solar cells.

An array is the collective name for a number of solar modules connected together.

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2 Industry observers reported in 2014 average module and cell prices fell 11% and 16%, respectively. See David Feldman, Robert Margolis, and Daniel Boff, Q3/Q4 ’14 Solar Industry Update, January 20, 2015, p. 32.
with direct government involvement, solar energy merely accounts for 0.5% of overall U.S. electricity generation. The Obama Administration actively supports greater deployment of solar energy and sees it as one way to encourage advanced manufacturing in the United States, create skilled manufacturing jobs, and increase the role of renewable energy technology in energy production, among other objectives. In its *Solar Progress Report: Advancing Toward a Clean Energy Future*, the Obama Administration argues that “The Administration’s investments have helped expand U.S. manufacturing capabilities, including new facilities to produce cost-effective, high quality solar panels as well as startup operations to commercialize novel PV and concentrating solar power (CSP) technologies.”

This report looks at the solar photovoltaic manufacturing industry and its supply chain; employment trends; international trade flows; and federal policy efforts aimed at supporting the industry. It does not cover other methods of solar-power generation, such as concentrating solar power plants. Concentrating solar technologies, largely dormant prior to 2006, are suitable mainly for utility-scale generation, whereas solar photovoltaics can be arranged in small-scale installations to produce power for individual buildings and in large installations to supply power to utilities.

Even with decreasing PV prices, producing equipment that generates solar power at prices competitive with electricity generated from fossil fuels remains a challenge. This is particularly true for utility-scale installations, as wholesale purchasers of electricity will compare the cost per megawatt hour of solar power directly with the cost of power from other sources. The cost-competitiveness of solar power is better in the residential and business markets, as the relevant comparison is with the delivered cost of electricity rather than with the generating cost. But even if the popularity of solar systems grows, falling equipment prices are likely to undermine efforts to sustain a solar manufacturing base in the United States.

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9 Two principal technologies—parabolic troughs and solar towers—are used in concentrated solar power installations that employ large arrays of mirrors to focus energy on a single point and result in tremendous amounts of heat, creating steam to turn turbines. CSP projects, which involve manufacturers such as Abengoa, AREVA, Brightsource Energy, Solar Reserve, Schott Solar, and Toresol are large-scale and require high initial investment; thus mainly utilities or large tower producers use this technology. In 2013, 885 MW of CSP was added worldwide, in contrast to the installation of 39 GW of solar PV. Concentrating Photovoltaic (CPV) technology, which has been around since the 1970s, uses optics such as lenses to concentrate a large amount of sunlight onto a small area of solar photovoltaic materials to generate electricity. According to the European Union’s 2013 PV Status Report, about 60 companies are developing new products for the CPV market, with the majority located either in the United States or Europe. Various analysts forecast that the CPV market could reach 500 MW by 2015 and 1 GW by 2020. The report can be found at http://iet.jrc.ec.europa.eu/remea/pv-status-report-2013.

10 The average price of PV modules fell to $1.15 per watt in 2012 from $1.59 per watt in 2011, a drop of 38%, according to EIA.
Solar Photovoltaic (PV) Manufacturing

Solar PV manufacturing, previously undertaken by numerous small firms, is rapidly maturing into a global industry dominated by a smaller number of producers. Cell manufacturers typically have proprietary designs that seek to convert sunlight into electricity at the lowest total cost per kilowatt hour. Vertical integration, whereby manufacturers produce their own components from wafers to modules, is becoming more common, but many PV manufacturers still rely on extensive supply chains for components such as wafers, glass, wires, and racks. Worldwide, the market for solar PV (including modules, system components, and installations) expanded from $2.5 billion in 2000 to $91.3 billion in 2013, according to one estimate.\(^{11}\)

The Manufacturing Process

PV systems do not require complex machinery and thousands of parts. In fact, most PV systems have no moving parts at all. They also have long service lifetimes, typically ranging from 10 to 30 years, with some minor performance degradation over time. In addition, PV systems are modular; to build a system to generate large amounts of power, the manufacturer essentially joins together more components than required for a smaller system. These characteristics make PV manufacturing quite different from production of most other types of generating equipment. In particular, PV systems offer little opportunity for manufacturers to make customized, higher-value products to meet unique needs. Manufacturers offer competing technological approaches to turning sunlight into electricity, but many customers have no reason to care about the technology so long as the system generates the promised amount of electricity. Economies of scale are significant, as increasing output tends to lower a factory’s unit costs.

Crystalline silicon PV is the main technology used by solar manufacturers, and accounted for about 90% of global PV production in 2013.\(^{12}\) Production of a crystalline silicon system involves several stages:

- **Polysilicon Manufacturing.** Polysilicon, based on sand, is the feedstock for the PV and semiconductor industries. It is the material used to make the semiconductors that convert sunlight into electricity. Polysilicon accounts for about a quarter of the cost of a finished solar panel.\(^{13}\) Approximately 90% of demand for polysilicon comes from the solar PV industry.\(^{14}\) Production requires large processing plants that may cost of up to $1 billion to build.\(^{15}\) Historically,
polysilicon prices have been volatile because the construction of a new plant can add a large amount of supply to the market. A handful of manufacturers dominate polysilicon production. In 2013, the largest polysilicon manufacturer was GLC Poly from China, followed by Wacker-Chemie from Germany, Hemlock from the United States, and OCI from South Korea. In 2013, nearly half of the world’s polysilicon was produced by Chinese and South Korean companies.16

- **Wafer Manufacturing.** Using traditional semiconductor manufacturing equipment, wafer manufacturers, including companies such as Elkem, LDK Solar, Okmetic, Siltronic, Nexolon, and SunEdison (formerly MEMC), shape polysilicon into ingots and then slice the ingots into thin wafers.17 The wafers are then cut, cleaned, and coated according to the specifications of the system manufacturers.

- **Cell Manufacturing.** Solar cells are the basic building blocks of a PV system. They are made by cutting wafers into desired dimensions (typically 5 x 5 or 6 x 6 inches) and shapes (round, square, or long and narrow). The manufacturer, such as Yingli, Trina Solar, or Sharp, then attaches copper leads so the cell can be linked to other cells. Minimizing the area covered by these leads is a key issue in cell design, as the lead blocks sunlight from reaching parts of the cell surface and thus reduces potential energy output. The U.S. Department of Energy (DOE) estimated in 2011 that a manufacturing plant to produce 120 megawatts (MW) of cells per year would require an investment of around $40 million.18

- **Module Manufacturing.** Modules, which normally weigh 34 to 62 pounds, are created by mounting 60 to 72 cells on a plastic backing within a frame, usually made of aluminum.19 Chinese manufacturers have come to dominate module manufacturing,20 making up about 70% of the total global production in 2013.21 The module is covered by a special solar glass, which protects the unit against the elements and maximizes the efficiency of the unit that converts sunlight into power. Production of solar glass is highly capital intensive, and approximately 60% of the global market is controlled by four manufacturers: Ashai, NSG Group (Pilkington), Saint Gobain, and Guardian.22 The glass is expensive to ship, so

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20 According to SolarBuzz, China’s Yingli Green, Trina Solar, and Canadian Solar were the largest manufacturers of modules by megawatts shipped in 2013. The U.S. manufacturer First Solar dropped to seventh in the world in 2013 from second place in 2012. Other rankings may differ according to what is counted and when.
glass producers tend to locate near module manufacturers.\textsuperscript{23} In some countries, module manufacturing is highly automated; in others, more labor-intensive processes are used.

A newer technology, thin-film PV, accounts for about 20% of total solar PV production.\textsuperscript{24} Rather than using polysilicon, these cells use thin layers of semiconductor materials like amorphous silicon (a-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), or cadmium telluride (CdTe). The manufacturing methods are similar to those used in producing flat panel displays for computer monitors, mobile phones, and televisions: a thin photoactive film is deposited on a substrate, which can be either glass or a transparent film. Afterwards, the film is structured into cells. Unlike crystalline modules, thin-film modules are manufactured in a single step. Thin-film systems are usually less costly to produce than crystalline silicon systems, but have substantially lower efficiency rates.\textsuperscript{25} On average, thin-film cells convert 5%-13% of incoming sunlight into electricity, compared to 12%-21% for crystalline silicon modules.\textsuperscript{26}

Looking ahead, relatively newer thin-film technology may offer greater opportunities for technological improvement.\textsuperscript{27} In the United States, First Solar is the largest thin-film panel manufacturer, with an annual production capacity of 280 MW.\textsuperscript{28}

Crystalline silicon systems and thin-film systems all make use of a variety of other components, known as “balance of system” equipment. These include batteries (used to store solar energy for use when the sun is not shining), charge controllers, circuit breakers, meters, switch gear, mounting hardware, power-conditioning equipment, and wiring. In the United States, inverters are also needed to convert the electricity generated from direct current (DC) to alternating current (AC) electricity compatible with the electric grid. Usually, balance of system components are not made by the system manufacturers, but are sourced from external suppliers.

Similar to many other advanced manufacturing industries, solar panel manufacturing depends on a global supply chain (see \textbf{Figure 1}), with PV manufacturers sourcing products at each stage of the value chain from suppliers located anywhere in the world. For instance, PV manufacturers purchase the majority of their solar factory equipment for wafer, cell, and module production from European and U.S. firms such as Roth & Rau (Germany), Applied Materials (United States), GT Solar (United States), and Oerlikon Solar (Switzerland). As an example, a system produced by the U.S. firm SunPower may include wafers from its AUO joint venture partner in Malaysia,
Each solar panel assembler uses different sourcing strategies, and the levels of vertical integration vary across the industry. At one extreme, SolarWorld, based in Germany, is highly integrated, controlling every stage from the raw material silicon to delivery of a utility-scale solar power plant. At the other extreme, some large manufacturers are pure-play cell companies, purchasing polysilicon wafers from outside vendors and selling most or all of their production to module assemblers. A number of solar manufacturers seem to be moving toward greater vertical integration for better control of the entire manufacturing process. Vertical integration also reduces the risk of bottlenecks holding up delivery of the final product.

Labor costs account for less than 10% of production costs for U.S. solar cell and module producers. According to Suntech, a Chinese module manufacturer, labor makes up 3%-4% of the cost of making crystalline solar panels. A 2011 study by the U.S. International Trade Commission (ITC) reported that even the more labor-intensive module assembly process is being automated, and that module assembly in China and the United States uses similar levels of automation. International transport costs for finished modules are also small, in the range of 1%-3% of value, producers have told the ITC.

Production and transportation costs do not appear to be the major considerations in determining where manufacturing facilities are located. In 2011, according to a National Renewable Energy Laboratory presentation, Chinese producers had an inherent cost advantage of no greater than 1% compared with U.S. producers; in the U.S. market, China suffered a 5% cost disadvantage before the imposition of antidumping and countervailing duties in 2012 and 2015.

Production Locations

With neither labor costs nor transportation costs being decisive, many manufacturers that opened new facilities over the past decade chose to locate them in countries with strong demand—which generally have been countries with attractive incentives for PV installations. Worldwide, the biggest markets have been Europe (principally Germany, Italy, and Spain) and Japan. Together, they comprised about two-thirds of the world’s PV installed capacity of nearly 139 GW in 2013. Since 2011, a number of European governments have reduced solar incentives such as feed-in tariffs (FITs), which require utilities to purchase renewable power at generous rates. These policy changes contributed to lower demand for solar PV installations in Europe, adversely affecting European solar manufacturing. In Germany, for example, the market decreased significantly. In 2013, 40 companies manufactured 1,230 MW of PV cells and modules, compared with 62 PV companies with production of about 2,700 MW in 2008. The Japanese government has sustained its domestic solar PV market by offering various inducements, which include a feed-in tariff, tax incentives, and direct grants for solar PV. South Korea, China, Malaysia, and the Philippines also provide various types of support to their domestic solar manufacturing sectors.

30 USITC, Crystalline Silicon Photovoltaic Cells and Modules from China, Publication 4360, November 2012, Table VI-2, p. VI-4.
32 USITC, Crystalline Silicon Photovoltaic Cells and Modules from China, Publication 4295, December 2011, p. 40.
38 Unlike some European countries, Japan continues to support renewable energy. On July 1, 2012, its Renewable Energy Law came into force, which introduced FITs for solar, wind, biomass, geothermal and small hydro.
The U.S. market for PV products has grown in recent years, accounting for about 12% of global PV installations in 2013 (see Figure 2).\textsuperscript{39} One reason for the increase was the development of leasing and financing options that lower up-front costs to households and businesses. SEIA reports cumulative PV capacity in the United States reached almost 5 GW at year-end 2013. Of new installations linked to the electric grid during 2013,

- 23% were for commercial or other non-residential customers, excluding utilities;
- 60% consisted of utility-scale installations, which generally use the largest panels and provide electricity directly to the electric grid; and
- 17%, the smallest share, were for residential buildings.\textsuperscript{40}

![Figure 2. U.S. PV Installations and Global Market Share](image)


**Notes:** The annual installed figures cover only grid-connected capacity. DC stands for direct current, the type of power output by photovoltaic cells and modules.


Domestic Production

In the United States, manufacturers produced PV modules with a capacity of 715,000 peak kilowatts\(^\text{41}\) (kW) in 2012. By value, combined U.S. PV cell and module shipments totaled about $7 billion in 2012.\(^\text{42}\) As shown in Table 1, SolarWorld and First Solar accounted about half of total domestic module production.

### Table 1. Cell and Module Production in the United States

<table>
<thead>
<tr>
<th>Company</th>
<th>Location of Headquarters</th>
<th>Technology</th>
<th>Cells</th>
<th>Modules</th>
<th>% of U.S. Module Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>SolarWorld</td>
<td>Germany</td>
<td>Mono/Multi c-Si</td>
<td>412</td>
<td>243</td>
<td>25.6%</td>
</tr>
<tr>
<td>First Solar</td>
<td>United States</td>
<td>CdTe</td>
<td>229</td>
<td></td>
<td>24.1%</td>
</tr>
<tr>
<td>Sharp</td>
<td>Japan</td>
<td>Mono/Multi c-Si</td>
<td>116</td>
<td></td>
<td>12.2%</td>
</tr>
<tr>
<td>Suniva</td>
<td>United States</td>
<td>Mono/Multi c-Si</td>
<td>102</td>
<td>63</td>
<td>6.6%</td>
</tr>
<tr>
<td>SunPower</td>
<td>United States</td>
<td>Mono/Multi c-Si</td>
<td>61</td>
<td></td>
<td>6.4%</td>
</tr>
<tr>
<td>All Others</td>
<td></td>
<td></td>
<td>8</td>
<td>237</td>
<td>25.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>522</td>
<td>949</td>
<td>100.0%</td>
</tr>
</tbody>
</table>


**Notes:** C-Si stands for crystalline silicon. Monocrystalline PV cells are usually cut from a single grown silicon ingot, while multicrystalline PV cells are manufactured such that wafers are made from multiple crystals. Monocrystalline PV cells have an efficiency of 16% to almost 20%, while the cheaper to produce multicrystalline PV cells achieve an efficiency of 14% to 15%. Thin-film PV is based on other materials such as amorphous silicon (a-Si), cadmium telluride (CdTe), or copper indium diselenide (CIGS).

SEIA reports the U.S. solar manufacturing sector in 2014 was made up of about 75 production sites that manufacture primary PV components (polysilicon, wafers, cells, modules, and inverters) and more than 450 additional domestic facilities that manufacture other PV-related products such as racking hardware and manufacturing equipment.\(^\text{43}\) SolarWorld’s Oregon facility is the largest solar cell and module plant in the United States, with the capacity to produce 500 MW of solar cells per year at full production. Other foreign-based firms, such as Sanyo Solar and SMA Solar, also operate PV primary component plants in the United States.

As shown in Figure 3, manufacturing facilities for primary solar PV equipment and components are located throughout the United States, with concentrations in California, Oregon, Ohio, Texas, and Washington. Due to the global supply chains prevalent in the PV industry, the amount of

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\(^\text{41}\) Peak gigawatts indicate the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1 billion watts per square meter and 25 degrees Celsius).

\(^\text{42}\) Value includes charges for cooperative advertising and warranties, but does not include excise taxes and the cost of freight or transportation. EIA, *Solar Photovoltaic Cell/Module Shipments Report 2012*, December 2013, Table 2, p. 8, http://www.eia.gov/renewable/annual/solar_photo/. In 2012, cell shipments totaled nearly $1.7 billion, and module shipments reached $5.3 billion.

\(^\text{43}\) SEIA data provided to CRS from its National Solar Database, November 2014.
domestic content may vary considerably from one plant to another. The map does not include announced facilities that have yet to start operating.

A closer look at SEIA’s data shows that in 2014, roughly two dozen U.S. facilities either produced raw materials for the PV industry or were involved in wafer/ingot production. About another 50 facilities made cells or assembled modules, and some 30 were involved in the production of solar inverters. SEIA’s list does not include other parts of the PV supply chain, such as equipment for the PV industry or other balance of system components.

Figure 3. U.S. Cell/Module and Polysilicon Production Facilities
(2014)

Source: SEIA, October 31, 2014.
Notes: This map is not inclusive of all PV facilities in the United States.

Challenging market conditions have led to numerous bankruptcies and manufacturing consolidations among solar firms. Consequently, several manufacturers have recently reduced, idled, or closed their U.S. operations, including Suntech, Kyocera, and Schott Solar. Other manufacturers such as Hemlock Semiconductor and GE Energy have abandoned their plans to

44 Totals by production line do not add to the number of individual PV manufacturing sites because some sites produce more than one product line.
45 Suntech, the only Chinese module manufacturer with a production plant in the United States and the world’s largest cell and module manufacturer in 2011, filed for bankruptcy in 2014. Wuxi Suntech acquired by Shunfeng Photovoltaic has more than 2,000 MW of annual production capacity in China.
46 Hemlock Semiconductor, “Hemlock Semiconductor Group Closes Tennessee Manufacturing Facility as a Result of (continued...)
build new solar factories in the United States. Generally, PV production facilities appear to have relatively short life spans, at least in the United States. A large share of the facilities that have closed operated for less than five years (see Table 2).

Table 2. Selected Recent PV Facility Closures

<table>
<thead>
<tr>
<th>Company</th>
<th>Status</th>
<th>Year Online</th>
<th>Year Closed</th>
<th>State</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abound Solar</td>
<td>Closed</td>
<td>2009</td>
<td>2012</td>
<td>CO</td>
<td>Module</td>
</tr>
<tr>
<td>Evergreen Solar Inc.</td>
<td>Closed</td>
<td>2008</td>
<td>2011</td>
<td>MA</td>
<td>Wafers</td>
</tr>
<tr>
<td>Helios USA</td>
<td>Closed</td>
<td>2010</td>
<td>2013</td>
<td>WI</td>
<td>Modules</td>
</tr>
<tr>
<td>MEMC Southwest Inc.</td>
<td>Closed</td>
<td>1995</td>
<td>2011</td>
<td>TX</td>
<td>Ingots</td>
</tr>
<tr>
<td>Nanosolar</td>
<td>Closed</td>
<td>2009</td>
<td>2013</td>
<td>CA</td>
<td>Modules</td>
</tr>
<tr>
<td>MX Solar</td>
<td>Closed</td>
<td>2010</td>
<td>2012</td>
<td>NJ</td>
<td>Modules</td>
</tr>
<tr>
<td>SolarWorld Americas</td>
<td>Closed</td>
<td>2007</td>
<td>2011</td>
<td>CA</td>
<td>Modules</td>
</tr>
<tr>
<td>Solon America Corp.</td>
<td>Closed</td>
<td>2008</td>
<td>2011</td>
<td>AZ</td>
<td>Modules</td>
</tr>
<tr>
<td>Solar Power Industries</td>
<td>Closed</td>
<td>2003</td>
<td>2011</td>
<td>PA</td>
<td>Cells, modules</td>
</tr>
<tr>
<td>Solyndra Inc.</td>
<td>Closed</td>
<td>2010</td>
<td>2011</td>
<td>CA</td>
<td>Modules</td>
</tr>
<tr>
<td>SpectraWatt Inc.</td>
<td>Closed</td>
<td>2009</td>
<td>2011</td>
<td>NY</td>
<td>Cells</td>
</tr>
<tr>
<td>BP Solar</td>
<td>Closed</td>
<td>1998</td>
<td>2012</td>
<td>MD</td>
<td>Cells, modules</td>
</tr>
<tr>
<td>Energy Conversion Devices</td>
<td>Closed</td>
<td>2003</td>
<td>2011</td>
<td>MI</td>
<td>Cells, modules</td>
</tr>
<tr>
<td>Suntech</td>
<td>Closed</td>
<td>2010</td>
<td>2013</td>
<td>AZ</td>
<td>Modules</td>
</tr>
<tr>
<td>Sharp Solar</td>
<td>Closed</td>
<td>2003</td>
<td>2014</td>
<td>TN</td>
<td>Modules</td>
</tr>
<tr>
<td>Sanyo</td>
<td>Closed one factory</td>
<td>2003</td>
<td>2012</td>
<td>CA</td>
<td>Wafers</td>
</tr>
</tbody>
</table>


a. Helios USA and MX Solar were two of the seven petitioners in the 2011-2012 solar trade case against China.
b. SolarWorld purchased the California facility from Royal Dutch Shell in 2006 and expanded it with a $30 million investment. It remains open for sales and marketing activities, but production was moved to Oregon.
c. SpectraWatt was a 2008 spinoff from an internal research project by the Intel Corporation. The company began shipments from its New York facility in 2010.
e. Sharp Solar ended production in Memphis, TN, in March 2014 to focus on its domestic Japanese market.

(...continued)


A considerably smaller number of manufacturers have opened or announced plans to open new U.S. manufacturing plants or expand existing ones. 49 1366 Technologies in Massachusetts 50 and Mission Solar in Texas 51 are among the solar factories that have opened since 2012. Stion, a CIGS thin-film manufacturer in Mississippi, announced that it expects to increase its solar panel manufacturing capacity in 2015. 52 In 2014, Suniva began construction of a second solar PV facility in Michigan. 53

Because of the widespread use of global supply chains, the presence of solar PV manufacturing in the United States does not imply a high level of U.S. content. Estimates dating to 2010, before the imposition of dumping and countervailing duties on imports from China, indicated that U.S. content accounted for 20% of the value of U.S.-installed crystalline silicon modules and 71% of the value of U.S.-installed thin-film modules. The level of U.S.-sourced content was estimated to be significantly higher for inverters (45% in 2010), mounting structures (94% in 2010), and combiner boxes and miscellaneous electrical equipment (59% in 2010). 54

U.S. Solar Manufacturing Employment

As shown in Figure 4, the solar manufacturing sector supported 32,490 jobs nationwide in 2014, according to SEIA. This accounted for only about one-fifth of U.S. employment related to the solar energy sector. 55 The remaining 80% of the 141,317 full-time workers employed directly in the solar power industry as of November 2014 are involved in other segments of the industry including installation, sales and distribution, project development, research and development, and finance. U.S. government data indicate that employment in PV manufacturing may be much lower than the SEIA figures suggest. According to EIA, the number of full-time equivalent employees in the U.S. photovoltaic industry was 12,575 in 2012. 56
The number of solar manufacturing jobs has been relatively flat since 2012, even as total employment in the solar energy industry increased, according to figures from SEIA. This is not surprising, as the majority of PV cells and modules are made overseas, including many that are manufactured by U.S. companies at offshore facilities. Domestic producers or assemblers of PV cells and modules do not employ a large number of workers. For example, SolarWorld had fewer than 1,000 production workers in 2013, and Suniva expects to employ a few hundred production workers when its newest factory in Michigan becomes fully operational. First Solar reportedly has more than 1,000 workers at its factory in Ohio. These estimates, combined with the number of solar cell and module manufactures that have shuttered their operations in recent years, suggest that the near-term prospects for increased employment in solar manufacturing seem limited.

Solar manufacturing was responsible for a tiny sliver of the more than 12 million domestic manufacturing jobs in 2014. Even if there is a substantial increase in U.S. solar manufacturing capacity, solar PV manufacturing seems unlikely to become a major source of jobs. Employment growth is likely to depend not only upon future demand for solar energy, but also on corporate decisions about where to produce solar PV systems and components.

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57 The Solar Foundation, *National Solar Jobs Census 2014*, January 2015, p. 6. The Solar Foundation collects information on solar industry employment by surveying a “known universe” of firms in various segments of the industry, including construction, manufacturing, and sales and distribution, to fill the gap in government data. The Solar Foundation states that its national job census should be viewed as conservative, and that there may be more solar workers in the United States than reported in the annual survey.

Global Production Shifts

The creation of incentives for solar installations in several countries around 2004 led many companies to enter the PV industry. More recently, the industry has entered a phase of rapid consolidation on a global basis. According to an estimate by SEIA, the number of module manufacturing facilities in the United States shrank from 51 in 2011 to 38 in 2013. Chinese cell production has been relatively flat because demand in some countries has declined and prices have weakened (see Figure 5). According to the International Energy Agency, there are now fewer than 100 Chinese PV module and cell manufacturers, compared with more than 300 companies in 2011.59 By the end of 2017, China aims to reduce the number to 10 major producers that would supply 70%-80% of domestic demand.60 Price pressures have driven a number of manufacturers, including the U.S. firms Evergreen Solar and Solyndra and the German companies Solon and Q-Cells, into bankruptcy, and have led others to lay off workers.

![Figure 5. Annual Solar Cell Production by Country](image)

*Source: Data compiled by the Earth Policy Institute from GTM Research, http://www.earth-policy.org/data_center/C26.*

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According to IEA-PVPS, China produced approximately two-thirds of the world’s solar modules in 2013, and it ships the lion’s share of all the PV modules that it produces to markets worldwide. In 2013, China’s exports of modules totaled about 16.7 GW, worth about $10 billion. Its domestic market for solar PV installations was small, at 19 GW in total installed PV capacity in 2013, but an increase from less than 1 GW in 2010. Driving this growth are policies to expand domestic solar PV demand, including direct grants for solar PV installations. More recently, China implemented a nationwide feed-in tariff. India aims to boost its domestic solar market to 20 GW of grid-connected electricity by 2022 using government programs like its National Solar Mission.

Ten firms now control nearly half of global solar module production. Of these, six are based in China, two in Japan, one in South Korea, and one in the United States (see Table 3).

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Table 3. Top PV Solar Module Manufacturers by Production

<table>
<thead>
<tr>
<th>Rank</th>
<th>Manufacturer</th>
<th>Location of Headquarters</th>
<th>% of Module Production</th>
<th>Founded</th>
<th>Plant Locations (current and planned)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yingli(^a)</td>
<td>China</td>
<td>8.3%</td>
<td>1998</td>
<td>China</td>
</tr>
<tr>
<td>2</td>
<td>Trina Solar</td>
<td>China</td>
<td>6.7%</td>
<td>1997</td>
<td>China</td>
</tr>
<tr>
<td>3</td>
<td>Sharp(^b)</td>
<td>Japan</td>
<td>5.4%</td>
<td>1959</td>
<td>Japan</td>
</tr>
<tr>
<td>4</td>
<td>Canadian Solar(^c)</td>
<td>China</td>
<td>4.9%</td>
<td>2001</td>
<td>China</td>
</tr>
<tr>
<td>5</td>
<td>Jinko Solar</td>
<td>China</td>
<td>4.6%</td>
<td>2006</td>
<td>China</td>
</tr>
<tr>
<td>6</td>
<td>Renesola</td>
<td>China</td>
<td>4.5%</td>
<td>2005</td>
<td>China</td>
</tr>
<tr>
<td>7</td>
<td>First Solar(^d)</td>
<td>United States</td>
<td>4.2%</td>
<td>1990</td>
<td>United States, Malaysia</td>
</tr>
<tr>
<td>8</td>
<td>Hanwha SolarOne(^e)</td>
<td>South Korea</td>
<td>3.3%</td>
<td>2004</td>
<td>China, Malaysia, Germany</td>
</tr>
<tr>
<td>9</td>
<td>JA Solar</td>
<td>China</td>
<td>3.2%</td>
<td>2005</td>
<td>China</td>
</tr>
<tr>
<td>10</td>
<td>Kyocera</td>
<td>Japan</td>
<td>3.1%</td>
<td>1996</td>
<td>Japan, China, Czech Republic, Mexico</td>
</tr>
</tbody>
</table>


- b. Sharp closed its factories in the United States and Europe.
- c. Canadian Solar, incorporated in Canada, manufactures most of its solar modules in China.

U.S. Trade in Solar Products

As part of their global business strategies, U.S. solar panel manufacturers source a significant share of components outside the United States. Imports of solar cells and panels nearly tripled from 2009, reaching $3.6 billion in 2013. Since 2009, imports of solar equipment rose every year, except for 2013, when PV imports shrank 29% from a year earlier (see Table 4).\(^{65}\) The import decline may be related to the imposition of U.S. antidumping and countervailing duties on Chinese-manufactured solar cells in 2012, which resulted in double- and triple-digit tariffs on imports of PV products from China.

\(^{65}\) The primary harmonized tariff schedule codes covering crystalline silicon PV cells, modules, or panels are HTS 8541.40.60.30 (cells) and HTS 8541.40.60.20 (modules), with a few import shipments also falling under HTS 8501.60.00.00 and 8507.20.80.
Most solar cells and modules imported into the United States come from Asia (see Table 4). Mexico is a relatively small exporter of PV modules to the United States, and its exports have been declining as manufacturers have closed some Mexican plants. Although U.S. imports of PV products from South Korea rose through 2012, South Korean manufacturers such as Hyundai Heavy Industry, LG Solar, and Samsung are reevaluating their business plans for the solar PV sector, contributing to a sharp drop in exports to the United States in 2013.66 South Korea’s stated goal of capturing 10% of the global PV market by 2020 may no longer be realistic.

### Table 4. U.S. Imports of Solar Cells and Modules, Selected Countries

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>% Change 2009-2013</th>
<th>% Change 2012-2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaysia</td>
<td>$55</td>
<td>$139</td>
<td>$563</td>
<td>$1,470</td>
<td>$1,210</td>
<td>2,106%</td>
<td>-18%</td>
</tr>
<tr>
<td>China</td>
<td>$419</td>
<td>$1,192</td>
<td>$2,804</td>
<td>$1,686</td>
<td>$1,144</td>
<td>173%</td>
<td>-32%</td>
</tr>
<tr>
<td>Taiwan</td>
<td>$109</td>
<td>$264</td>
<td>$154</td>
<td>$408</td>
<td>$556</td>
<td>410%</td>
<td>36%</td>
</tr>
<tr>
<td>Mexico</td>
<td>$349</td>
<td>$481</td>
<td>$514</td>
<td>$482</td>
<td>$439</td>
<td>26%</td>
<td>-9%</td>
</tr>
<tr>
<td>Philippines</td>
<td>$172</td>
<td>$28</td>
<td>$242</td>
<td>$390</td>
<td>$97</td>
<td>-44%</td>
<td>-75%</td>
</tr>
<tr>
<td>World</td>
<td>$1,446</td>
<td>$2,645</td>
<td>$4,977</td>
<td>$5,103</td>
<td>$3,628</td>
<td>151%</td>
<td>-29%</td>
</tr>
</tbody>
</table>

Source: Global Trade Atlas. These statistics cover only solar cells and panels (HS 8541.40.6020 and HS 8541.40.6030).

### International Trade Conflicts

Protracted trade cases involving solar equipment manufacturing have been initiated by the United States, China, the European Union, and India. The first case started in October 2011, when the Coalition for American Solar Manufacturing (CASM), led by the U.S. unit of SolarWorld, along with MX Solar USA, Helios Solar Works,67 and four unnamed companies,68 filed antidumping and countervailing duty petitions with the U.S. Department of Commerce (DOC) and the International Trade Commission (ITC). SolarWorld and CASM alleged that Chinese makers of crystalline silicon photovoltaic cells and modules had injured U.S. producers by selling their products in the United States at below-market prices, and that the Chinese government had provided illegal subsidies to these manufacturers.69 The CASM petition asked DOC to levy tariffs

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67 In 2013, Helios Solar Works filed for receivership (a process similar to bankruptcy) and closed its solar panel factory in Wisconsin. The company is now owned by Chinaland Solar Energy, which reportedly may open a solar panel plant in North Carolina.

68 Four petitioners remained anonymous, fearing retaliation by China. CASM represents more than 250 members with around 22,000 employees. Other groups publicly supporting the trade action include the United Steelworkers. For more information, see the CASM website at http://www.americansolarmanufacturing.org.

69 In the United States, there are two dispute-resolution systems specifically designed to handle company complaints about apparently anticompetitive trade practices: antidumping and countervailing duty mechanisms. The process for (continued...)
of up to 250% on solar cells and modules imported from China. Upon finishing their respective investigations in late 2012, DOC\(^70\) and the ITC\(^71\) each ruled these products had been unfairly priced and subsidized. In the first case, the final antidumping duties on solar cells and modules imported from China ranged from 18.3% to 249.9%, with the majority of tariffs at 24.5%. Countervailing duties ranged from 14.78% to 15.97%.\(^72\) U.S. Customs and Border Protection will collect these duties at least through October 31, 2017.\(^73\) In December 2014, the World Trade Organization (WTO) appellate body said that U.S. countervailing duties on Chinese solar panels breached global trade rules.\(^74\)

After the United States imposed tariffs on Chinese PV producers, the Chinese government brought its own antidumping and countervailing duty cases against polysilicon imported into China from the United States and South Korea. In January 2014, the Chinese government responded by issuing final antidumping rates on U.S. polysilicon producers, which included antidumping margins of 57% for REC Silicon, 53.3% for Hemlock Semiconductor, and 53.7% for MEMC (now known as SunEdison).\(^75\) China followed up with countervailing duties on U.S. polysilicon of up to 6.5%.\(^76\) The tariffs do not apply to imports into China from the United States of silicon used in the production of exported modules, which allows U.S. firms to continue to supply polysilicon to Chinese ingot and wafer manufacturers.

(...continued)

antidumping and countervailing duty cases such as the one initiated by CASM can be divided into five stages, each ending with a finding by either DOC or the ITC. These stages with the deadlines governed by statute are as follows: (1) initiation of the investigation by the DOC (20 days after filing the petition); (2) the preliminary phase of the ITC’s investigation into whether U.S. producers have been injured (with a preliminary determination within 45 days after filing of the petition); (3) the preliminary phase of the DOC investigation (with a preliminary determination within 190 days after the ITC’s determination for antidumping cases or within 130 days for countervailing duty cases); (4) the final phase of the DOC investigation (with a final determination within 75 days for a CVD case and within 135 days in AD cases); and (5) the final phase of the ITC’s investigation (with a final determination within 45-75 days). CRS Report IF10018, *Trade Remedies: Antidumping and Countervailing Duties*, by Vivian C. Jones, gives an overview of the antidumping and countervailing duty process.


\(^73\) After issuing an antidumping (AD) or countervailing duty (CVD) order, if requested by an interested party, DOC may conduct annual administrative reviews of AD or CVD orders, during the anniversary month of an order. The outcome of a review may raise or lower the actual AD or CVD assessments for the period of review. After five years, the department initiates a sunset review to determine whether to continue or revoke the order.


SolarWorld and CASM responded positively to the duties levied by the United States against China in the 2011-2012 investigation.\(^7^7\) Still, SolarWorld and some Members of Congress objected to its scope, which they claimed should have been extended to solar modules made in China that incorporate solar components from other countries such as Taiwan.\(^7^8\) SolarWorld argued that the “loophole” resulted in Chinese manufacturers avoiding the punitive duties by using slightly more expensive Taiwan-manufactured solar cells to make U.S.-bound solar modules in China.\(^7^9\) In 2014, SolarWorld, with the continued support of CASM, filed new antidumping and countervailing duty cases with the ITC and DOC.\(^8^0\) Unlike the 2012 petitions, the 2014 cases included both PV cells and modules made in China, and the antidumping investigation extended to PV cells and modules made in Taiwan. In a final decision in December 2014, DOC announced antidumping margins ranging from 26.71% to 165% for Chinese exporters, and countervailing duties from 27.64% to 49.79%. For Taiwanese companies, the antidumping duties range from 11.45% to 27.55%.\(^8^1\) The ITC confirmed DOC’s final decision, setting an effective date for the new antidumping and countervailing of February 5, 2015.\(^8^2\)

SEIA\(^8^3\) and the Coalition for Affordable Solar Energy (CASE)\(^8^4\) strongly opposed the second SolarWorld/CASM petition. They claim higher tariffs on PV imports from China would curb domestic demand for solar products by substantially increasing costs in major segments of the U.S. solar industry. In addition, they argue the tariffs erode profit margins across the PV value chain. CASE attributes any injury to the U.S. industry on polysilicon pricing, thin-film panel competition, and the loss of U.S. government incentives. In 2013, SEIA proposed a negotiated solution to avoid further escalation of the solar trade frictions between the United States and China.\(^8^5\) The SEIA proposal would require China to revoke its tariffs on solar imports by China,


\(^7^8\) Eight Members of Congress, including Senators Ron Wyden and Sherrod Brown, wrote to Rebecca Blank, then Acting Secretary of Commerce, on September 27, 2012, urging DOC to expand the investigation to include modules containing cells manufactured in countries outside of China. To view the letter, see http://www.wyden.senate.gov/download/?id=283b6c18-c246-4b23-a576-4b846809e682&download=1.


that the United States remove its duties for at least five years, and that Chinese manufacturers pay into a U.S. Solar Manufacturing Settlement Fund to support U.S. manufacturers.86

Solar equipment disputes have expanded beyond the United States and China. For example, the European Commission brought trade cases against solar products from China, which, in August 2013, resulted in a government-to-government agreement limiting imports and setting a floor price on China’s solar exports to the European Union.87 In another case, the United States filed a WTO action against India because of its domestic content requirements, which the United States claims discriminate against U.S. solar cells and modules.88

**U.S. Exports**

U.S. PV exports to the world remain small, at slightly more than $350 million in 2013, shrinking from a high of $1.4 billion in 2010. In 2013, Japan and Germany were the two largest foreign markets for U.S. solar PV exports, at $162 million and $44 million, respectively. PV cell and module exports from the United States to China were valued at $14.4 million in 2013. A DOC analysis predicts that in 2015, Canada and Chile will account for more than half of all U.S. exports of solar products.89

U.S. exporters of solar cells and panels generally do not face foreign tariffs because of the Information Technology Agreement, whose signatories have agreed to eliminate duties on information technology products.90 Tariffs in other parts of the PV value chain are also comparably low. For example, the applied tariff on silicon is between zero and 4% in the leading cell- and module-producing countries.91 However, non-tariff barriers can be significant, including local content requirements at the national level or sub-national level in places like India, Canada, South Africa, and Saudi Arabia and other policies that encourage the use of local content in countries like Italy.

Besides these mandates, import charges and taxes, customs procedures, and divergent product standards can hinder trade in solar PV components in markets such as Korea and Japan.92

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90 Generally, solar cells and modules enter foreign markets under the harmonized tariff schedule (HTS) 8541.40.60.20 and 8541.40.60.30, which are included in the Information Technology Agreement. The EU, Canada, Japan, India, Malaysia, and China are among its signatories. Absent are some large countries such as Brazil, which charges a 12% duty rate on most imported solar equipment, both PV and thermal. Background on the Information Technology Agreement can be found on the WTO website at http://www.wto.org/english/tratop_e/inftec_e/inftec_e.htm.
91 Silicon enters foreign markets under HTS 2804.61. The EU’s applied tariff is zero, China’s is 4%, Malaysia’s is zero, and the Philippines’ is 3%. South Korea’s applied tariff is 3% for non-FTA member countries, but because of the U.S.- Korea Free Trade Agreement, the duty rate for silicon exports from the United States to South Korea is zero.
Subsidies for domestic production in major overseas markets like China are another potential constraint on U.S. exports. Talks on environmental goods launched in June 2014 among 14 WTO countries, including the United States and China, seek to address non-tariff barriers, including trade remedies, which impose higher trade costs. Several U.S. government programs encourage the export of renewable energy products. Targeting large emerging markets like India, the Export-Import Bank provides direct loans to solar manufacturers through its Environmental Products Program, under which it allocates a certain portion of funding to renewable energy and energy-efficient technologies. Recent Ex-Im Bank beneficiaries in the solar sector include MiaSole, which received a $9 million direct loan to support the export of solar modules to India, SolarWorld, which received a $6.4 million guarantee to finance the export of solar modules to Barbados, and Suniva, which got a $780,000 loan guarantee for solar module exports to Mexico.

U.S. Government Support for Solar Power

Federal policies favoring development of a domestic solar power sector include support for the U.S. solar PV manufacturing industry as well as incentives for solar generation of electricity. Three of the five programs listed below have expired.

- An advanced energy manufacturing tax credit (MTC) was aimed at supporting renewable energy manufacturers. It reached its funding cap in 2010.
- The Section 1705 Loan Guarantee Program directed funds to manufacturing facilities that employ “new or significantly improved” technologies. The program expired in 2011.
- The investment tax credit (ITC) provides financial incentives for solar power at a rate of 30%. Without legislative action, the ITC is due to end on December 31, 2016, after which it will revert to a permanent rate of 10% for commercial investments and expire for residential investments.

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• The Section 1603 Treasury Cash Grant Program requires solar projects to have commenced construction by December 31, 2011, and to complete construction by December 31, 2016.

• The Sunshot Initiative is one of several DOE programs to support the solar industry and increase domestic PV manufacturing.

Advanced Energy Manufacturing Tax Credit

The Advanced Energy Manufacturing Tax Credit, Section 48C, which was included in the American Recovery and Reinvestment Act of 2009, provided a 30% tax credit to advanced energy manufacturers that invested in new, expanded, or reequipped manufacturing facilities built in the United States. Solar panel manufacturing was among the 183 projects funded through the MTC before it reached its cap of $2.3 billion in 2010. Plants receiving the credit had until February 17, 2013, to begin operations. Solar PV manufacturers benefiting from the credit included Abound Solar, Calisolar, MiaSole, First Solar, Sharp, Suniva, Suntech, and Yingli. At least three PV manufacturers that received tax credits under the 48C program—Xunlight, Abound, and Sharp—have closed their factories. Despite the Obama Administration’s request for another $5 billion for the 48C credit, Congress has not allocated additional money for the program.

DOE Loan Guarantee Programs

The Section 1705 loan guarantee program was a temporary program established under the American Reinvestment and Recovery Act (P.L. 111-5) to provide loan guarantees for renewable energy projects including solar manufacturing and solar power generation projects. A Congressional Research Service report found that solar projects accounted for more than 80% of the of the Section 1705 loan guarantees, totaling $13.27 billion. The loan guarantee program included 16 solar projects, of which four were manufacturing projects. Of the four manufacturers, Solyndra declared bankruptcy in late 2011 and defaulted on its $535 million loan, Abound Solar received about $70 million of its $400 million loan before shuttering its solar panel operation and filing for bankruptcy in 2012, and SoloPower never met the requirements to initiate its $197 million loan guarantee. 1366 Technologies, which received a $150 million guarantee, is the…

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98 The credit was authorized in Section 1302 of the American Recovery and Reinvestment Act.


100 A full list of the projects selected for the tax credit is available at http://www.whitehouse.gov/the-press-office/president-obama-awards-23-billion-new-clean-tech-manufacturing-jobs.


102 The remaining 18% supported a variety of projects in other renewable energy sectors including biofuels, energy storage, wind generation, transmission, and geothermal electricity. See CRS Report R42059, Solar Projects: DOE Section 1705 Loan Guarantees, by Phillip Brown.

103 In 2013, SoloPower closed its factory in Oregon, and DOE pulled the company’s 1705 loan guarantee funding. SoloPower changed its name to SoloPower Systems Inc. in summer 2013, and it announced plans in 2014 to restart its manufacturing operations.
only participant still actively manufacturing solar PV equipment. The Section 1705 loan program expired on September 30, 2011.

**Investment Tax Credit (ITC)**

The Investment Tax Credit for solar was first adopted as part of the Energy Tax Act of 1978, and has been continuously available since that time (when there have been lapses, the credit has been retroactively extended). The current ITC, allowing residential and commercial owners of solar projects to offset 30% of a solar system’s cost through tax credits, is in place through the end of 2016 when it is scheduled to revert back to a permanent rate of 10% for commercial investments and lapse entirely for residential investments. In practice, developers of utility-scale solar projects often do not have sufficient income to benefit from the credit, so projects have been developed through structures that transfer the benefit to third-party “tax equity” investors.

In 2009, as part of ARRA, the ITC was modified and a new program was adopted which provided a new tax option for solar power developers: a direct cash grant, which may be taken in lieu of the federal business energy investment tax credit that they were otherwise entitled to receive. In the 113th Congress, the Renewable Energy Parity Act of 2014 (S. 2003) was introduced by Senators Michael Bennet and Dean Heller to make firms eligible for tax credits for projects that are already under construction before the credit’s expiration date, instead of having to wait until those projects are competed and in service. More than two dozen Members of Congress have voiced their support for modifying the construction qualification to the solar investment tax credit to ensure that solar projects underway will come to fruition. Other Members argue for letting the credit drop to 10% in 2017 as planned because the solar industry no longer needs such incentives. It is uncertain what impact a reduction in the credit will have on solar installations across the United States.

**1603 Cash Grant Program**

The Section 1603 Treasury Grant program expired at the end of 2011. It allowed owners of renewable energy systems to apply for cash grants to cover 30% of the systems’ cost, regardless of their tax liability. Through October 15, 2014, the 1603 Treasury Program had awarded grants to more than 95,000 individual solar projects totaling $7.3 billion. While an ITC, which

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105 P.L. 95-618.

106 The current ITC rate of 30% was first introduced as part of the Energy Policy Act of 2005 (P.L. 109-58), and the eight-year extension of the commercial and residential solar ITC was part of the Emergency Economic Stabilization Act of 2008 (P.L. 110-343).

107 The permanent 10% rate for solar was part of the Energy Policy Act of 1992 (P.L. 102-486). The credit rate fluctuated between 10% and 15% between 1980 and 1992, as it was changed by numerous pieces of legislation during this time.


(continued...)
reduces overall tax liability, will still be available for solar projects until 2016, it is viewed as a less favorable incentive than the cash grant.

SunShot and Other DOE Initiatives

The U.S. Department of Energy, which has set a goal for solar energy to provide 14% of domestic electricity by 2030 and 27% by 2050, runs a number of efforts intended to create a stronger domestic PV manufacturing base, under the SunShot Initiative.110 These include

- the PV incubator program, which began in 2007 and aims to support promising commercial manufacturing processes and products;111
- the PV supply chain and cross-cutting technologies project, which provides up to $20.3 million in funds to non-solar companies that may have technologies and practices that could strengthen the domestic PV industry;112
- the Advanced Solar Photovoltaic Manufacturing Initiative (PVMI), with up to $112.5 million in funding over five years, to advance manufacturing techniques to lower the cost of producing PV panels;113 and
- SUNPATH, which stands for Scaling Up Nascent PV At Home and is funded at less than $45 million, aims to increase domestic manufacturing by supporting industrial-scale demonstration projects for PV modules, cells, substrates, or module components.114

A separate DOE program to strengthen PV manufacturing is the Advanced Research Project Agency-Energy program, or ARPA-E, which received $280 million in FY2014. ARPA-E funds transformative energy research that is not being supported by other parts of DOE or the private sector because of technical and financial uncertainty. As of August 2013, ARPA-E has funded 285 projects.115 1366 Technologies, a silicon PV company, and Applied Materials, a semiconductor production equipment manufacturer, are among the solar manufacturers to receive federal funding through this program.116

(continued)

111 According to DOE, the Sunshot Incubator Program has given 61 startup companies at total of 74 awards since 2007. For more information, see U.S. Department of Energy, Photovoltaic Technology Incubator, http://www1.eere.energy.gov/solar/pv_incubator.html.
113 For more information on these programs, see DOE, SunShot Photovoltaic Manufacturing Initiative, http://www1.eere.energy.gov/solar/sunshot/pvmi.html.
116 For ARPA-E projects and programs, see http://arpa-e.energy.gov/?q=arpa-e-site-page/projects.
Conclusions

Solar manufacturing continues to go through a shakeout, with manufacturers closing U.S. plants because of difficult global business conditions, stiff competition particularly from Chinese companies, and falling prices for solar panels. Beyond that, the extraction of large quantities of shale gas seems likely to lower the cost of generating electricity from natural gas, potentially reducing demand for solar panels.117 While state-level renewable fuels standards, which require utilities to obtain a certain proportion of their electricity from renewable sources, may provide continuing demand for utility-scale PV installations in some states, the lower cost of gas-fired generation may limit interest.

In some parts of the United States, residential and commercial PV systems produce electricity at prices competitive with conventional grid electricity, once subsidies are taken into account. However, although the per-watt cost of solar PV systems has declined significantly, in most areas of the country solar power is still not competitive with power generated from fossil fuels. The cost disadvantage could widen if subsidies are unavailable or if retail electricity prices decline due to the lower price of natural gas. In the absence of continued government support for solar installations or for the production of solar equipment, the prospects for expansion of domestic PV solar manufacturing may be limited.

Appendix. Historical Overview

Modern photovoltaic technology traces its roots back to 19th-century breakthroughs by scientists from Europe and the United States. In 1839, a French physicist, Alexandre Edmond Becquerel, discovered the photovoltaic effect, and in 1883, an American inventor, Charles Fritts, made the first primitive solar cell. Progress in modern solar cell manufacturing began in the 1940s and 1950s when Russell Ohl discovered that a rod of silicon with impurities created an electric voltage when illuminated and three scientists at Bell Laboratories in New Jersey (Daryl Chapin, Calvin Fuller, and Gerald Pearson) developed the first commercial photovoltaic cell.

Further advancing PV cell manufacturing was the space race of the 1960s, with the competition between the United States and the former Soviet Union driving demand for solar cells, which were, and still are, used to power some spacecraft and satellites. The first generation of photovoltaic manufacturing firms included such names as Hoffman Electronics, Heliotek, RCA, International Rectifier, and Texas Instruments. The technology, however, remained too expensive for other uses, and the market remained very small. The Japanese manufacturer Sharp pioneered the use of photovoltaics on earth, using them to power hundreds of lighthouses along the Japanese coast, but it could not identify other applications for which photovoltaics were cost-competitive.

The oil crises of the 1970s hastened the development of modern solar panels by a second generation of PV firms, which focused on ground applications. Major oil and gas companies entered the field. Exxon underwrote the Solar Power Corporation. Atlantic Richfield Company (ARCO) purchased Solar Technology International and renamed it ARCO Solar in 1977; its corporate descendant is now part of SolarWorld, presently the largest cell manufacturer in the United States. First Solar, one of the biggest manufacturers of PV thin-film cells, can trace its roots to Toledo, OH, where it was established in 1984 as Glasstech Solar.

The first direct federal support for solar manufacturing was during the Carter Administration. The Energy Tax Act (ETA) of 1978 provided tax credits for homeowners who invested in solar and

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118 The photovoltaic effect is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons—packets of solar energy. These photons contain different amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.

119 Fritts made his first cell from selenium. The semiconductor had a thin coat of gold around it and was not very effective in generating electricity. The reason, now known, is that selenium is not a very good semiconductor.

120 In 1958, PV solar cells received considerable attention because they partially powered the Vanguard 1 satellite launched by the United States. PV cells power nearly all of today’s satellites because they can operate for long periods with virtually no maintenance.

121 Heliotek merged with Spectrolab, and produces high-efficiency cells today.


123 Oil and gas companies used solar power to protect wellheads and underground pipelines from corrosion and to power navigational aids on offshore oil rigs.

124 Elliott Berman, who founded Solar Power Corporation, pioneered a number of manufacturing changes including buying cheap solar wafers that had been cast aside by the semiconductor industry, which helped to reduce the cost of solar cells, lowering the selling price from $100 per watt in 1970 to $20 per watt in 1973.

125 P.L. 95-618. ETA created residential solar credits of up to $2,000 for devices installed on homes. They were in (continued...
certain other technologies. Additionally, the federal government through the Public Utility Regulatory Policies Act required utilities to purchase power produced by qualified renewable power facilities.126

Notwithstanding this support, production of solar PV power in the United States remained small. By the mid-1980s, domestic photovoltaic manufacturers were selling products at a loss, and many were struggling. President Reagan’s Tax Reform Act of 1986 reduced the Investment Tax Credit (ITC) to 10% in 1988, where it remained until 2005. Because of these policy changes, combined with the sustained drop in petroleum prices, solar manufacturing slumped until 2005, when President George W. Bush signed the Energy Policy Act (EPAct).127 That law included a 30% ITC for property owners who installed commercial and residential solar energy systems.128

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effect from April 20, 1977 to January 1, 1986.

