



Achieving American Leadership in the Solar Photovoltaics Supply Chain

Key Findings and Opportunities

Developing U.S. photovoltaic (PV) manufacturing could mitigate global supply chain challenges and lead to tremendous benefits for the climate as well as for U.S. workers, employers, and the economy.

The solar supply chain is global and reliant on products from China or companies with close ties to China.

Significant growth in U.S. manufacturing across the supply chain is possible with incentives that offset the higher cost of manufacturing in the United States.

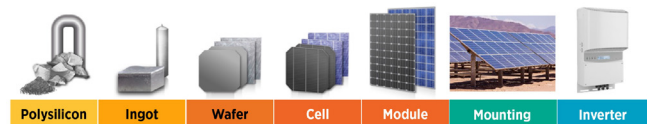
Existing polysilicon production facilities are currently idle or supplying polysilicon to other industries. Expansion in the ingot and wafer sectors outside of China would create demand for existing U.S. polysilicon producers to run at high capacity.

The United States can expand production of thin-film modules, which do not rely on obtaining materials from Chinese companies. The thin film supply chain is concentrated in Ohio.

There is a cluster of solar module manufacturers in

Alabama, Florida, and Georgia, which presents an opportunity to grow a competitive supply chain of module components in the region.

U.S. Solar Market and Supply Chain Overview



The solar supply chain: Polysilicon is melted to grow monocrystalline silicon ingots, which are sliced into thin silicon wafers. Silicon wafers are processed to make solar cells, which are connected, sandwiched between glass and plastic sheets, and framed to make PV modules. Then, they are mounted on racking structures and connected to the grid using an inverter.

The United States is the second largest global PV market, representing about 10%-15% of global PV demand. PV cells made from crystalline silicon dominate the market, representing 84% of the U.S. market; cadmium telluride (CdTe) thin films represent 16% of the U.S. market.

Most PV modules installed in the United States

are imported. While many components can be sourced outside of China, about 97% of the world's production of silicon wafers occurs in China.

Using imported cells, about 2 GW of silicon modules were made domestically in 2020. There is no active U.S.-based ingot, wafer, or silicon cell manufacturing capacity, and polysilicon production capacity is not being used for solar applications.

The concentration of the supply chain in companies with close ties to China, a country with documented human rights violations and an unpredictable trade relationship with the United States, is already creating disruption in the solar supply chain.

Greatly expanding U.S. PV manufacturing could mitigate global supply chain challenges and lead to tremendous benefits for the climate as well as for U.S. workers, employers, and the economy.

To reestablish domestic solar manufacturing in the United States, companies that produce and sell solar components will require financial support to offset the 30-40% higher cost of domestic solar production.

To fully realize the benefit of solar power to society, its costs and benefits must be distributed equitably, the entire supply chain must be operated in a safe and socially responsible manner, the input materials must be produced without forced labor, and recycling at end-of-life must become standard practice.

Supply Chain Mapping

Input materials

Metallurgical-grade silicon (MGS), glass, resins to make encapsulant and backsheets, and aluminum are input materials for the solar supply chain. MGS is made from high-grade quartz. China produces around 70% of global MGS and produces half the world's rolled aluminum. The United States has restricted imports from Hoshine Silicon, the world's largest producer of MGS, as part of a government response to evidence of forced labor in Xinjiang.

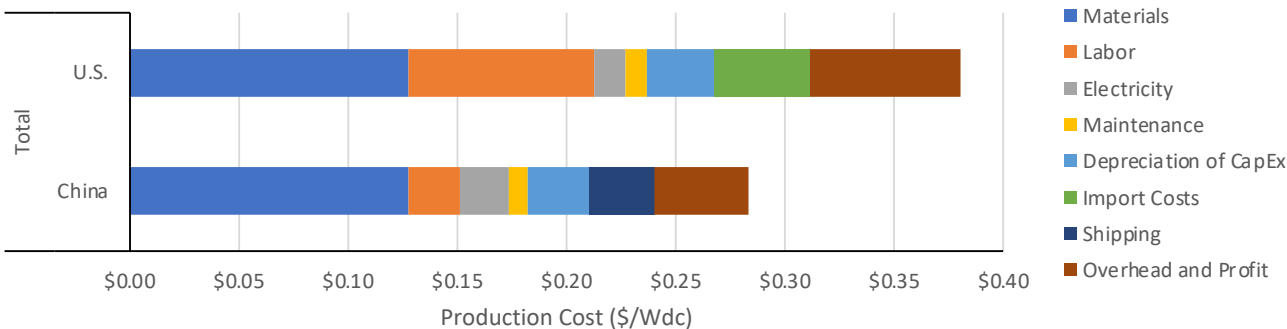
There may be domestic capability to produce encapsulant, backsheets, aluminum for frames, and some PV glass applications.

Polysilicon Refining

MGS is refined into high-purity polysilicon. 54% of Chinese polysilicon is produced in Xinjiang, although this share is expected to decrease. U.S. plants are operating significantly under capacity since Chinese tariffs were placed on U.S. polysilicon in 2014. The Uyghur Forced Labor Prevention Act (UFLPA) presumptively prohibits all products originating in Xinjiang from being imported unless an importer can prove via clear and convincing evidence that an entity's goods are not produced using forced labor.

Restarting solar polysilicon production requires demand for domestic polysilicon, which does not currently exist because nearly all silicon ingot are made in China.

Silicon PV Manufacturing Costs in the United States and China



Ingots/Wafers

Polysilicon is converted into ingots that are sliced into wafers. About 97% of the world's production of silicon wafers occurs in China. There has been no production of solar wafers in the United States since 2016.

There is an opportunity to develop an effective “kerfless” method of wafer manufacturing, which would likely have a significant cost advantage. Expansion in the ingot and wafer sectors outside China would create demand for existing U.S. polysilicon producers to run at higher capacity.

Solar Cell Fabrication

Wafers are converted to cells through a series of chemical and physical steps including screen printing of silver contacts. About 75% of the silicon solar cells installed in the United States are made by Chinese subsidiaries located in just three Southeast Asian countries: Vietnam, Malaysia, and Thailand.

The United States was once the world leader in silicon solar cell technology, and remnants of that expertise are still available that could be leveraged to help start domestic cell production.

Module Assembly

Module assembly involves electrically connecting cells in an array, sandwiching them between layers of encapsulant and glass surrounded by an aluminum frame. Using imported cells, U.S. module assembly scaled up significantly in 2018 and 2019, primarily due to U.S.-placed tariffs on imported modules. This production has been around the same level as the PV cell exemption in the Section 201 tariffs.

There is a cluster of module manufacturers in Alabama, Florida, and Georgia, which presents an opportunity to grow a competitive supply chain of module components in the region.

Mounting Structures

PV mounting structures are made of steel components

that hold PV panels in place. 70% of utility-scale solar systems use single-axis tracking. The two largest tracker vendors are U.S. firms, which represent 70% of 2020 U.S. tracker shipments, and the United States possesses much of the relevant intellectual property.

International shipping of mounting structures is a significant fraction of their cost, which makes domestic production more competitive, however tariffs on imported raw steel and aluminum have led multiple firms to decrease U.S. production.

Inverters

PV inverters convert the energy generated by PV modules into energy that can be used by electrical grids. The inverter supply chain varies by inverter type, but the domestic market relies heavily on inverters from companies headquartered in Europe and Japan.

There are currently no international standards for inverters so the country that establishes them will have a first-mover advantage.

Thin Film Technology

Cadmium (Cd) and tellurium (Te) are the primary elements used to make thin-film CdTe modules. CdTe accounted for approximately 16% of all U.S. PV capacity through 2020 and 29% of utility-scale capacity. U.S. company, First Solar, is the global leader in CdTe manufacturing and is the largest U.S. solar module producer today.

The United States can expand production up to the limit that CdTe material availability allows, with little risk of being overtaken by low-cost foreign competition.

Policy Next Steps

Significant financial support and incentives from the U.S. government as well as strategic actions focused on workforce, manufacturing, human rights, and trade

will facilitate a global solar industry aligned with U.S. interests and the reestablishment of robust U.S. domestic solar manufacturing.

Strategies for executive action and recommendations for Congressional action to spur domestic manufacturing include:

- Enact legislation to **provide tax incentives to support domestic manufacturing**, including incentives for building new facilities and for the ongoing operation of those facilities. Silicon ingot and wafer production should be prioritized.
- **Enact legislation to encourage domestic solar adoption and deployment.** Extend and revise credits for clean energy deployment, such as the Production Tax Credit (PTC) and Investment Tax Credit (ITC) to provide stronger incentives for solar projects that support domestic manufacturing and increase family-sustaining jobs.
- **Coordinate trade policy across the U.S. government** to create fair conditions for the U.S. solar industry and its workers. ■

Download the full document and the corresponding other documents that are part of the DOE response to the supply chain executive order at:
www.energy.gov/policy/supplychains