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RECLAIMING THE US SOLAR SUPPLY CHAIN FROM CHINA

The current state of the US solar manufacturing industry and its future prospects.

CPA WHITE PAPER

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COALITION for a PROSPEROUS AMERICA

Reclaiming the US Solar Supply Chain from China

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Key Points

- Several US solar module manufacturers have ramped up production substantially in the last three years under the stimulus of the Section 201 safeguard tariffs on solar module imports, leading US producers to achieve a 10-year high in market share of 19.8% in 2019, a noteworthy achievement.
- The Section 201 solar tariffs have had no negative impact on the US market for solar energy installations, which grew 43% in 2020. Solar installations are set to be more than 50% greater than they were expected to be prior to the implementation of the 201 tariffs in 2017.
- However, Chinese manufacturers continue to hold a dominant, near-monopoly, position in several important sectors of the upstream solar supply chain, endangering the health and future of the US solar industry. China continues to raise the stakes with large subsidies supporting billions of dollars of Chinese solar industry expansion. Beijing's goal is global dominance of this industry.
- Chinese dominance threatens US energy independence and US technology leadership in solar and other clean energy technologies. It also threatens our semiconductor industry, which relies on polysilicon as a raw material.
- The US government should implement policies designed to secure the long-term future of an end-to-end US solar supply chain, using a mixture of incentives, tax credits, government procurement policies, and tariffs. These policies should be explicitly long-term. They should not be conditional on any foreign nation's behavior. Their goal should be to achieve US resilience and self-sufficiency in solar power technology and manufacturing.

CONTENTS

The State of the US Solar Industry

The US solar industry continues to post very strong growth figures, with 2020 expected to have delivered 19 gigawatts (GW) of solar installations, an increase of 43% over 2019 and an all-time high for the US market. This report focuses on the state of the US solar manufacturing industry, which manufactures the hardware (solar panels and components that go into solar panels) that makes solar power possible. Despite a decade of relentless assault by the Chinese solar manufacturing industry, which is government-subsidized and dependent on forced Uyghur labor, the US solar module manufacturing industry has grown to its largest size and healthiest condition since 2010. This report looks at the current state of the US solar manufacturing industry and its future prospects.

The US solar industry withstood the COVID pandemic better than almost any other major US industry. The growth was strong at both ends of the industry: residential installations at the smaller system size, and utility installations at the larger end. The industry suffered a decline in installations in the second quarter of 2020 due to COVID shutdowns freezing installation work in many states, but bounced back sharply in Q3 and Q4. Figure 1 shows the strong growth in 2020, as well as continued growth expected this year and in the following two years. The data comes from solar market analysts Wood Mackenzie. The surge in installations in 2016 was driven by concern in the industry that tax credits would end that year, so customers rushed to buy equipment and install systems before the end of that year. The next year was depressed largely due to the after-effects of the 2016 surge. Growth resumed in 2019 and gathered speed thereafter.

Figure 1: Forecast for 2020 shows 43% growth in solar installations to 19 Gigawatts (GW).

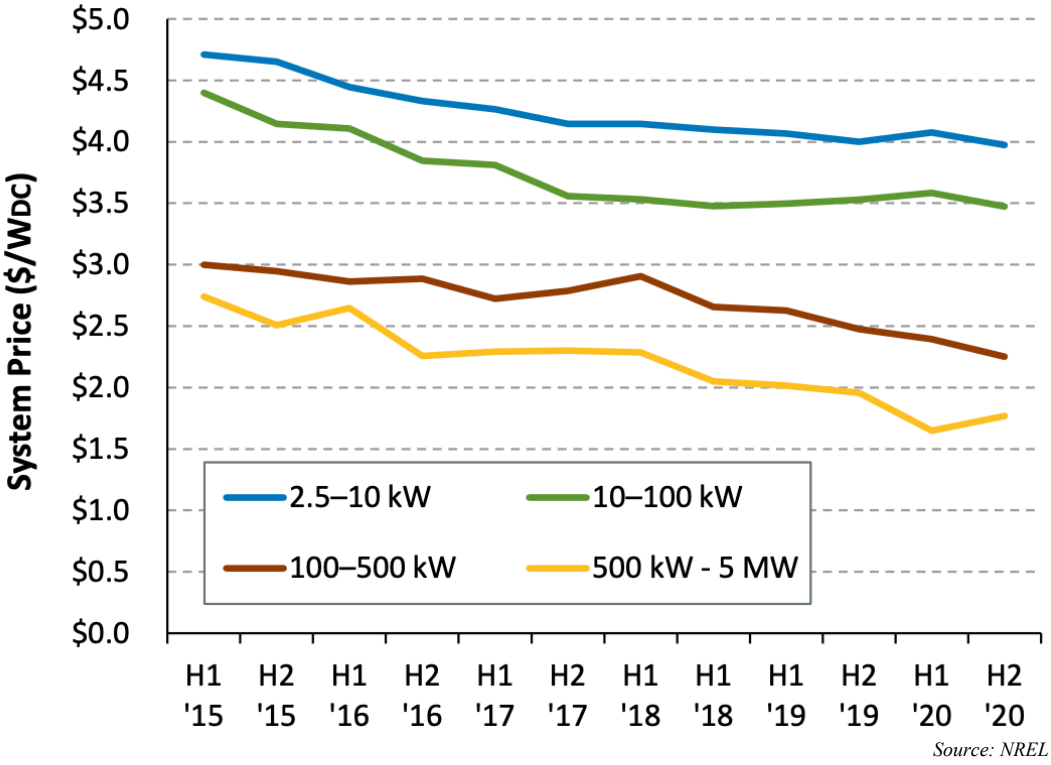
The growth in solar installations is driven by two major forces: declining prices for solar equipment, and federal and state tax credits. Figure 2 shows that system prices have fallen by around 20% over the last five years, defying predictions of price hikes due to tariffs. Compared with solar prices 15 years ago when the technology first became commercially viable, prices have declined about 90%. The fundamental driver in price decline is growing efficiency in the design and manufacture of the solar cell, the heart of photovoltaic energy production. Solar cells have become steadily more efficient at converting light into electricity, reducing the cost per watt.

China too has played a role in declining solar system prices. The Chinese government views solar as a strategic industry, and as such, the solar sector has received numerous subsidies, including in land, electricity, indirect and direct financial support in addition to tax relief. This fueled an unrestrained race to the bottom in which Chinese firms overinvested, dumped product to gain market share, and then consolidated the industry. Artificially cheap prices allowed for increased deployments, but it also hollowed out the U.S. solar manufacturing industry.

Solar deployment policies in the US have helped the industry grow. The federal investment tax credit (ITC) has played a large role in driving residential, commercial, and utility investment in solar systems. The ITC, currently at 26%, and recently extended for two years, enables a business or homeowner to claim a credit against income tax equivalent to 26% of the cost of the entire solar project, including land acquisition, design, and installation of a solar system. The federal ITC is supplemented by a variety of state-level credits and support programs, especially the net metering program, which allows individuals or businesses to sell power back to regulated utilities at set rates. Solar power enjoys support from the public and from lawmakers because it is seen, and legitimately so, as it is cleaner than fossil fuels, less dangerous than nuclear power, and less visually intrusive than large-scale wind farms. Unfortunately, the solar tax credit is not limited to US-manufactured equipment, so a significant share of US taxpayer support is going to Chinese companies.

“The market today is rock solid and the tax credit extensions will only add fuel to the fire this year,” Solaria CEO Suvi Sharma told us. Solaria designs and installs custom solar systems for both the residential and the utility market. Sharma expects his revenue to double this year.

Figure 2: The price of an installed system has fallen by 20% in the last five years.



Source: NREL

From American Leadership to Chinese Dominance: Solar Power History

Solar cells were first invented in the US in 1954 at Bell Labs, by a team led by chemist Calvin Fuller. In the 1960s and 1970s, the US led the world in development of the technology, supported by government R&D funds and private research organizations like Bell Labs. The oil crisis of the 1970s provided further impetus to solar research, prompting lawmakers, business leaders, and scientists to search for alternatives to foreign oil. SunPower was founded as a private company in 1985 by academics at Stanford University and led the commercialization of solar cells. In the 1990s, Japan and Germany entered the industry with a substantial R&D and business presence in both their domestic and international markets.

In the early 2000s, growth in solar power deployment accelerated, due to environmental concerns and growing worries about Middle Eastern instability. SunPower expanded its manufacturing capacity internationally. In the US, hundreds of small startups raised billions of dollars to enter the solar power market, some with the dominant crystalline silicon cell technology and others with alternative technologies such as thin film solar panels. By 2005, euphoria surrounded the solar industry and related so-called "alternative energy fields." Thousands of engineers, scientists, manufacturing workers and investors joined and supported the industry. SunPower went public that year, and its stock closed 41% over the launch price on its first day of trading.

2005 was also the year the Chinese government decided to target alternative energy and solar power specifically as a key strategic growth industry for China. As a result, the Chinese government routed billions of dollars to China's nascent solar industry via Chinese state-owned banks, private banks, provincial and local governments, and other channels. According to one estimate, Suntech, once China's largest solar power company received low-interest loans of $3.7 billion from local banks in Wuxi. American academics Usha and George Haley documented that Chinese solar panel maker Evergreen received two thirds of its factory's capital costs from local provincial governments. One study found that in 2011, Chinese solar companies had an average profit margin of negative 40%. However, the Chinese government funded these massive losses as part of the price of cornering the global market.

In 2003, China had a 2% share of global solar manufacturing. By 2011, that share was more than 60%. In response to the rush of new supply from new Chinese factories, global solar prices cratered. In the US, scores of companies exited the industry. "In the US, $10 billion of investment was lost and over 100 companies went bankrupt," says Frank van Mierlo, CEO of 1366 Technologies, one of the few survivors.

Over the next few years, solar manufacturing in the US declined to near-zero. While solar deployments continued to rise, the US relied almost entirely on solar panels manufactured in Asia. Anti-dumping and countervailing duties were levied on Chinese solar products in 2012 and again in 2014. The large Chinese manufacturers simply avoided the duties by opening factories in southeast Asia.

The Impact of Safeguard Tariffs on US Production

In February 2018, the Trump administration levied tariffs on imported solar modules. Section 201 of the 1974 Trade Act allows the temporary imposition of "safeguard tariffs" when an increased volume of imports threatens the viability of a domestic industry. The investigation by the bipartisan International Trade Commission found a severe threat to the entire US solar industry and recommended tariffs on all imports. The tariffs started at 30% in 2018 and were scheduled to decline by 5 percentage points each year over a four-year period.

Even though the tariffs were only temporary, and four years is a relatively short time period in the manufacturing business, the 201 tariffs gave a kick-start to the industry. "The tariffs were like a bridge to the future," says Paul Mutchler, sales director at Mission Solar. After steady growth over the past two years, Mission Solar decided to expand further. It purchased new equipment and began installing it in December 2020. This spring, Mission expects to switch on its new assembly line, increasing its capacity by 50% to 300 megawatts. Based in San Antonio, Texas, Mission has just one manufacturing facility. It sells primarily to the residential sector, but also to commercial customers. Its panels are all made in the USA and appeal to customers who want to buy American. "We're the American muscle car of solar panels," Mutchler says.

Auxin Solar is an original equipment maker that manufactures solar panels sold under other companies' brand names. It was founded in San Jose, California by a group of former tech executives led by Mamun Rashid. Rashid had designed chips for Intel and retired, before coming back into business in 2008 because he wanted to manufacture in the US and he believed the solar business was set for strong growth. The Chinese invasion of the industry set back Auxin's plans.

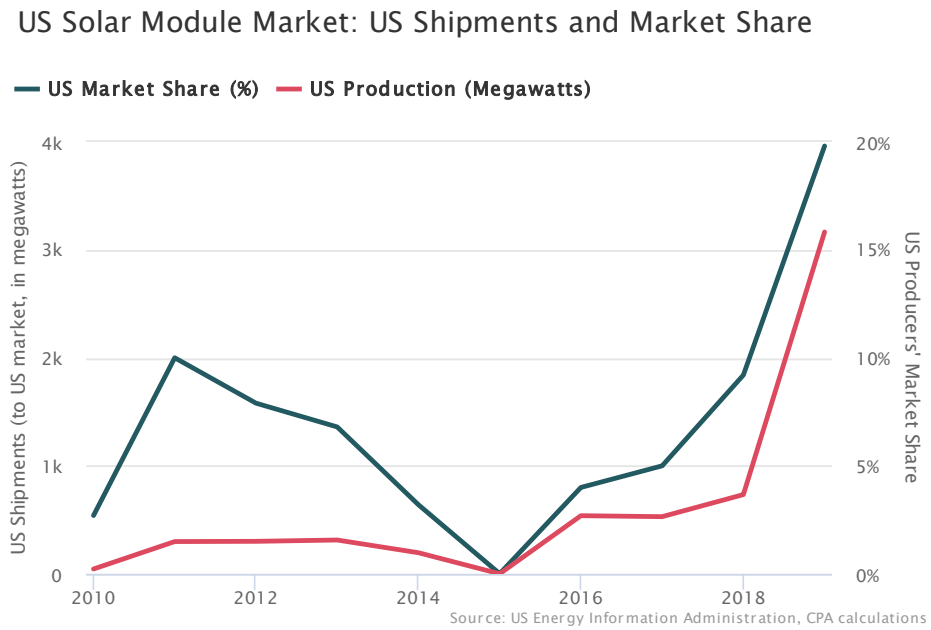
"We were dead wrong believing people wanted made in USA, and it cost us millions. People wanted the lowest price," Rashid says. In 2019, in the wake of the tariffs, Auxin's business surged. Production approached the 150 megawatt capacity at the San Jose plant for the first time in years. Like Mutchler, Rashid gives a lot of credit for the resurgence to the tariffs. "We are alive today because of the 201s," he says.

Three of the largest makers of solar modules on US soil are foreign-owned. Jinko Solar is a Chinese company, manufacturing modules in Jacksonville, Florida. LG Solar is a Korean company that opened a plant in Huntsville, Alabama in February 2019. Today the LG plant has a capacity of 550 megawatts and is working flat out, with 150 employees working in multiple shifts. The largest crystalline silicon solar module maker in the US is Korean-owned Hanwha Q Cells, with a plant in Dalton, Georgia employing around 650 workers producing at a rate of 1.7 gigawatts per year.

First Solar Corp. is the world's largest US-owned solar module maker. It is now producing at a rate of 2.2 gigawatts a year in the US (and another 5 GW of production in Asia). First Solar uses a thin film technology, which is different from other manufacturers. Instead of assembling several dozen solar cells into a solar panel or module, First Solar's technology involves spreading a thin layer of photovoltaic material onto a sheet of glass. Thin film was a "hot" technology a decade ago. Dozens of thin film startups and pioneers were wiped out when Chinese overcapacity made prices plummet between 2010 and 2012, with First Solar as the only commercially successful survivor. First Solar is expanding its two Ohio factories to handle demand for Series 6, the latest generation of its thin film modules. In 2020, demand for the Ohio product ran at an extraordinary 109% of capacity. In its Q4 earnings report, released on Feb.25th, First Solar said it expects to sell about $2.5 billion worth of modules in 2021.

In 2019, US-produced solar modules achieved a record market share of 19.8%, the highest figure in a decade, according to official figures from the Energy Information Agency, a division of the US Department of Energy. The 201 safeguard tariffs, implemented in 2018, were a major driver of the market share growth. In 2018, confidence in the growth of the renewable energy market was rising and the tariffs provided a boost to the market, signaling to module producers that this was the right moment to invest in expansion. The data for 2020 is not yet available, but we expect it to show a similar or even larger US share in the domestic market.

Figure 3: US Production of Solar Modules and US Market Share in the US Market 2010-2019



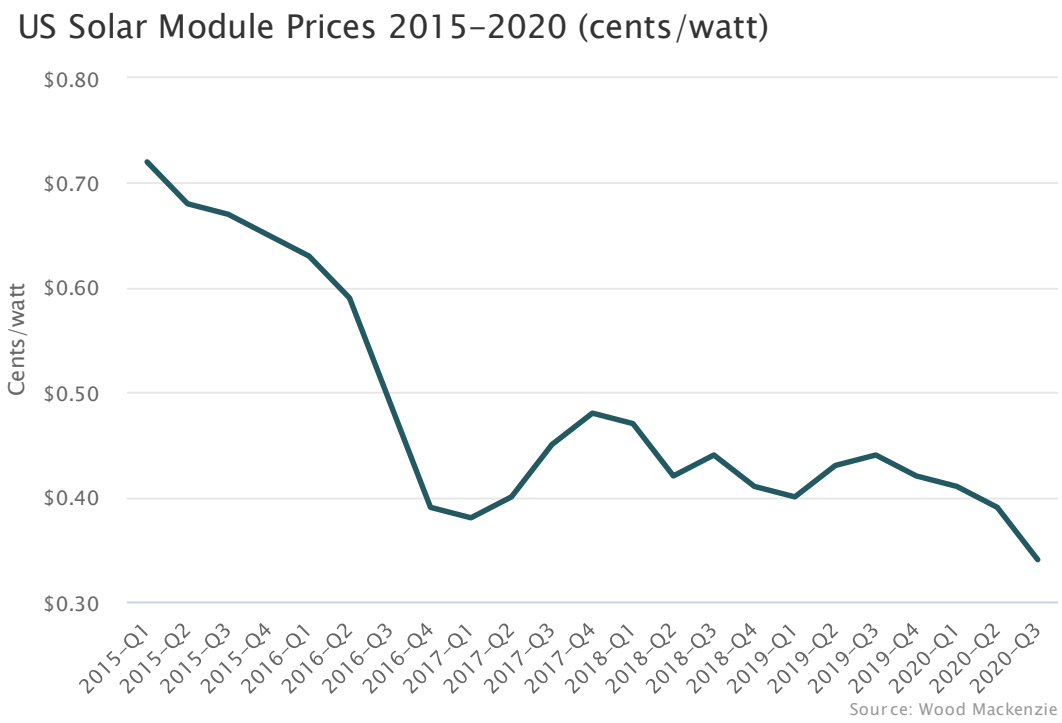
Predictions of Tariff Harm Did Not Materialize

The Section 201 safeguard solar tariffs have been opposed with a campaign led by groups representing Chinese producers, importers and installers using gloomy predictions that have not materialized during the tariff period. In a February 22, 2021 letter, the Solar Energy Industries Association (SEIA) argued that the solar tariffs have caused a loss of 62,000 solar jobs in the US and a loss of $19 billion of solar deployment business. These claims rely on misleading employment claims and flawed economic analysis.

First, there is little if any evidence that US tariffs have been fully passed on as a price increase to the purchaser. Figure 4 shows that solar module prices have fallen steadily from 2015 to today. Prices are down from 65 cents per watt in 2015 to 27 cents a watt in Q3 of 2020. Prices plunged sharply in 2016 as importers tried to unload large inventories of modules. In 2017 prices rose as importers paid more to import large volumes of modules ahead of the implementation of expected tariffs from the Trump administration.

Once the tariffs were levied in February 2018, instead of prices rising by the 30% level of the tariffs, they rapidly fell and have continued falling to this very day.

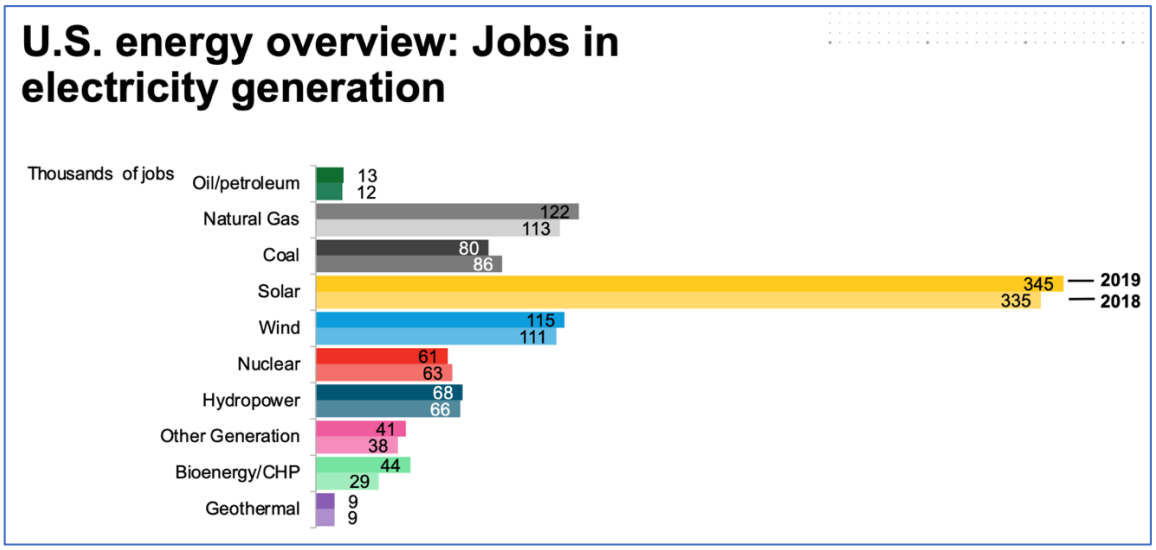
Figure 4: US Solar Module prices are falling at 8% a year.



Second, the claim that 62,000 jobs were lost due to tariffs does not reflect what actually occurred. Solar forecasts from SEIA and Wood Mackenzie published in 2017, before the tariffs were imposed, showed expected installations of around 15 GW for 2020. Actual installations in 2020, with the tariffs in place, exceeded 19 GW.

Job totals in solar are very high, according to estimates recently published (see Figure 5) by Bloomberg New Energy Finance.

Figure 5: BNEF Estimates of employment show solar employment higher than any other energy category.



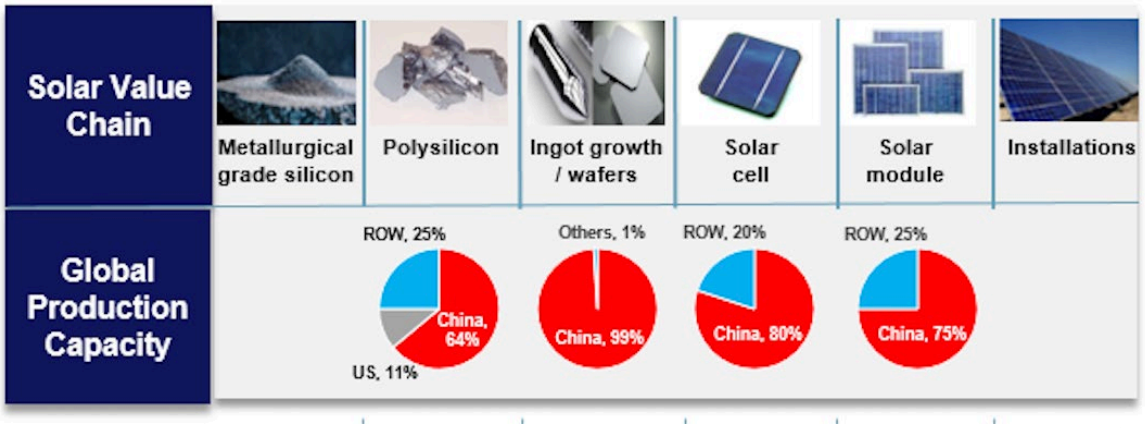
Source: BNEF Sustainable Energy Factbook 2021

The China Chokehold on the Solar Industry

While it is positive that US market share in solar modules rising sharply, module manufacturing is just one part of the solar power supply chain. Solar modules are assembled from solar cells, which are the workhorses of solar power generation. A solar cell is a silicon chip with other materials embedded that enable the chip to generate an electric current when hit by sunlight. The electricity is carried off the chip by tiny wires, normally made of silver. The manufacturing process begins with metallurgical-grade silicon, which is mined from rocks, often quartz (silicon is one of the most plentiful elements in the earth's crust). The silicon is then heated and purified up to purities of 99.9999% to make a crystalline form of silicon known as polysilicon. The polysilicon is shaped into long bars called ingots. The ingots are sliced into wafers. The wafers are manufactured into solar cells by depositing materials and contacts onto the wafer and then cutting them to the standard size of 6 inch square. Finally, the solar cells are assembled into solar panels, with a typical layout of 60 or 72 cells to a panel.

The pie charts in Figure 6 show the extent of Chinese domination of the industry today. The US has viable businesses only at the start of the supply chain, in the manufacture of polysilicon, and at the end of the process, in the manufacture of the solar module. China's domination of the middle stages, the manufacture of solar ingots and wafers, is near-total, at 99%. Its domination of global solar cell manufacture, at 80%, is also very powerful.

Figure 6: China dominates key segments of solar supply chain with shares up to 99%



Source: REC Silicon

The upstream businesses, making polysilicon, ingots, and wafers, lend themselves to China's form of government-managed industrial subsidy-driven mass production. These processes are energy-intensive so China's subsidized electricity enables the government to give Chinese companies a hidden cost advantage. Equally important is the use of forced labor in China's Xinjiang province. China has 64% of the world's production capacity of polysilicon. About half of that production occurs in Xinjiang. China has ample supplies of coal-fired power plants in Xinjiang producing low-cost energy. The irony of using highly polluting power plants to produce solar equipment should not be lost on us, and indeed US solar module producers like Mission Solar stress that they are focused on producing solar modules that minimize carbon emissions throughout the product lifecycle, from manufacture of the polysilicon all the way through to disposal and recycling of an old solar module.

The polysilicon, ingot, and wafer-making businesses are dominated by half a dozen Chinese companies including Daqo New Energy, GCL-Poly, Jinko Solar, and Longi. Chinese industries have repeatedly used the domination of one part of a supply chain to drive foreign competition out of other sections of the chain, resulting in a Chinese takeover of a complete supply chain. The danger of China exercising its chokehold to seize ever-larger market share is a very real threat and makes it difficult for US entrepreneurs to raise money to invest in US solar manufacturing projects.

The manipulation of industry-wide standards is another tool Beijing uses against international competitors. Following government direction, the Chinese solar industry is moving to a new standard power efficiency of 22.5%, up from the current 19.5% standard. That could put non-Chinese makers of solar cells in a difficult spot as they may struggle to raise the investment funds needed to upgrade their equipment. On the wafer side, some Chinese manufacturers are promoting a new target for standard wafer size of 210mm (8.25 inches) instead of the current standard of 156mm (6 inches). Each of these changes requires investing in new equipment, which can often cost hundreds of millions of dollars. This can drive non-Chinese firms out of the business. Chinese firms rely on cheap finance from China's network of government-directed banks, local authorities, and local power companies. One expert estimated in 2016 that China has spent a staggering $47 billion building its solar industry.

Polysilicon is a key industry segment under attack from Chinese producers. A recent report from a German analyst said China was planning increase its domination of polysilicon production by another 10 points of global market share, up to 75%. This will likely depress the price further, putting foreign producers in difficulty. Polysilicon is one sector where the US still has a significant presence, with three producers. After President Obama's antidumping/countervailing duty tariffs on Chinese solar modules in 2012, Beijing retaliated by putting prohibitively high tariffs on the import of US polysilicon into China. Since no solar ingots are produced in the US and few produced anywhere outside of China, the US poly industry relies on China as a market. The Chinese retaliation robbed the US poly industry of most of its business. One poly maker, REC Silicon, was forced to first downsize and then shut its Moses Lake, Washington poly plant with the loss of over 500 jobs. Then in December 2019, the Trump administration and the Chinese government concluded the so-called Phase One agreement. Under a confidential part of Phase One, China reportedly agreed to begin purchasing US-made polysilicon again. However, one industry source told us: "China has not bought a single gram of US polysilicon under Phase One."

Retaliatory tariffs on polysilicon have a sad history. In 2012, the Obama administration levied an anti-dumping duty averaging 31% on Chinese solar cells and modules. China responded with a 50% retaliatory tariff on US-made polysilicon. Also in 2012, Hemlock Semiconductor opened a new $1.2 billion polysilicon manufacturing facility in Clarksville, Tennessee. Hemlock is a joint venture of two large US chemical firms, Dow Chemical and Corning, and a Japanese chemical maker. Due to the Chinese tariff, Hemlock never shipped a single ton of polysilicon from Clarksville. Instead, in 2014 it was forced to shut the facility, lay off a total of 700 people, and bulldoze all the buildings. Over $1 billion of high-tech manufacturing buildings were plowed into the dirt.

Solar cells are another segment of the industry where US production has dwindled to near-zero. Violet Power, an Oregon startup, is working on building a greenfield solar cell plant in Moses Lake, Washington, adjacent to the REC Silicon facility. Violet Power CEO Desari Strader has said the plant will open this year and employ 500 workers, producing 500 megawatts of solar cells. This would be a very welcome development. But China is also investing heavily in solar cell production, with the aim of almost doubling its production of solar cells and modules from 94 GW to 180 GW between last year and this year. This is likely to put further pricing pressure on the US cell and module industry.

Forced Labor

At the same time that China levied its tariffs on US polysilicon, it launched a crash program to build up Chinese polysilicon production in the Xinjiang province in the west of China. This took place at the same time that President Xi launched a campaign of repression against the Muslim Uyghur population in Xinjiang. From about 4,000 metric tons of polysilicon production in 2012, Xinjiang today accounts for about half of global polysilicon output of 570,000 metric tons a year.

Last year, US consulting firm Horizon Advisory released an explosive report documenting the use of forced Uyghur labor in Xinjiang province. The report explained how polysilicon producers work closely with the Xinjiang Production and Construction Corps, a paramilitary Chinese government organization that is involved in the mass detention and physical abuse of

thousands of Uyghurs whose only crime is to be of a different ethnic group than the Han Chinese that rule China. The Horizon report said use of polysilicon linked to Xinjiang was "pervasive" throughout the Chinese solar industry.

The Biden administration has stated its public support for tough restrictions on products from Xinjiang, with Secretary of State Anthony Blinken recently reiterating his view that China policy in the province amounts to "genocide." Congress is likely to pass legislation this year calling for tougher restrictions on products incorporating Xinjiang forced labor. It is unclear how the US solar industry, led by its trade association the Solar Energy Industries Association, will respond. It has called for reorienting supply chains to exclude products from Xinjiang. But the Chinese solar panel makers, some of whom occupy key positions within the SEIA hierarchy have either refused to comment on their exposure to Xinjiang product or denied forced labor exists in Xinjiang. Some figures in the Chinese industry are calling for retaliation against American companies over what they call a forced labor "hoax," Industry sources tell us that Chinese poly makers are already moving some production to Mongolia, with the aim of claiming that export products come from Mongolia while Xinjiang poly will be targeted only to the Chinese market.

There is hope that other participants in the US market might react more vigorously on the forced labor issue. For example, NextEra Energy, one of the leaders in deploying renewable energy, gets its solar modules from Jinko, a Chinese solar giant that buys Xinjiang polysilicon from Daqo and makes ingots and wafers in Xinjiang. In 2019, Google agreed to buy solar energy from NextEra for its data centers. With its highly outspoken staff, Google has championed equity issues in the US and condemned racism linked to US slavery that was abolished in 1863. It remains to be seen if Google will take as firm a stand on the slavery and racism—including systematic mass rape in Xinjiang prisons recently reported by BBC News—now going on in Xinjiang. Investment analysts have told Standard and Poors that the investment community will take ethical standards into account when valuing solar stocks because renewable energy companies are "held to a higher standard" than ordinary companies. But despite their rhetoric, solar organizations like the SEIA have shown more flexible ethical standards.

China's goal is likely to use its dominant position in the upstream industry and its strong position (80% market share) in solar cells to force the US and other western nations into bankruptcy in those segments of the industry (polysilicon, modules) it does not yet control, on the way to consolidating complete domination of the global solar supply chain. A Chinese utility executive, Liu Zhenya, provided a glimpse of the China vision in 2016, when he gave a speech in which he outlined his vision for an international organization he called Global Energy Interconnection, to manage a global power grid relying on renewables for 80% of its energy, and which would one day unite virtually the entire world with highly efficient clean electricity. It would be, said Liu, a way to funnel cheap power from the global North to the South and from the East to the West. Unspoken was the thought that all this power would be generated largely from China by Chinese equipment, providing China huge leverage over all nations dependent on this global grid.

In the 1970s, the US was dependent on the Middle East for vital oil. That turned into a crippling weakness when OPEC enacted an embargo and fourfold price hike, leading to recession, inflation, and thorough re-evaluation of US foreign policy. It was a factor in Jimmy Carter's election defeat in 1980. As our nation moves towards getting the majority of our electricity from

renewable sources, it would be a tragedy if the US became completely dependent on China for this vital technology of the future.

Losing Manufacturing Means Losing Research and Development

It is often said that the US should focus on research and development (R&D) and leave manufacturing to other nations. This view ignores the reality of how technological progress is achieved in most industries. New products and new processes are typically not the result of scientists working in white coats in serene isolation in a government or university lab. They are much more likely the result of men and women working in industry, in close contact with the problems and opportunities of existing products. Government and university funding can play a key role, but in collaboration with industry. The original silicon solar cell was developed by Bell Labs because Bell's parent company, AT&T, was trying to solve the problem of getting electric power to telecom huts out in remote areas like deserts or mountains.

If the US loses all manufacturing capability in the solar supply chain, that R&D will also be lost to China. The strength of the US technology industry is in the entrepreneurs who are willing to take risks and the venture capital firms that are willing to back them. Frank van Mierlo is one such entrepreneur. He launched 1366 Technologies 13 years ago. It has developed a manufacturing process for turning polysilicon directly into silicon wafers using half the energy and generating half the carbon footprint of the current technology. Van Mierlo was a co-founder of Bluefin Robotics in 1997, a startup that developed the world's first commercial underwater robot or drone. Bluefin was acquired by General Dynamics and its drones are used today by the US Navy and by the airline industry for retrieval of planes that crash in the ocean. After Bluefin, van Mierlo launched 1366. He, the co-founders, and venture investors have poured a total of $200 million into 1366. Despite the technical and cost advantages of the 1366 wafer manufacturing process and van Mierlo's goal of manufacturing in the US, 1366 may be forced to manufacture in Asia because that's where the customers are.

"We [the US] have a massive comparative advantage in photovoltaics but China locks us out. They are not innovating in solar because it is so much cheaper to copy." If 1366 Technologies builds a manufacturing plant in the US, that would fill a missing link in the US supply chain with a superior technology. It would also benefit the US polysilicon industry, which would have a new customer.

Across the country, Chris Eberspacher runs a small startup called Tandem PV. They are developing a solar cell made of a perovskite crystal which can be layered on top of a conventional silicon solar cell to tap a different wavelength of light and generate some 30% more electricity from a given area of solar cells. Eberspacher and Tandem's founder, Colin Bailey, are both PhDs from Stanford. They raised a few million dollars of seed money from the federal government's ARPA-E research agency and venture capital firms. They are building a small production facility in Silicon Valley to manufacture and prove out the first versions of their tandem solar cells. Their business plan is to raise more venture money once the prototype is working, and then move to large-scale manufacturing. Eberspacher, who has been in the solar industry for 35 years, would like that manufacturing operation to be in the US. "Perovskites will be a global industry. The manufacturing can be done here because the labor cost input is low and the value of the product is high."

It's widely recognized in the industry that perovskites will be a key technology for the next decade. Eberspacher is worried because Chinese researchers are now at the leading edge, along with researchers from the US, Germany and the UK. "The federal government has to think holistically about what it wants. It's high time the US gets more serious about manufacturing and STEM education. Because it's very difficult to be a technology leader if you don't have a nexus to how products are manufactured."

A US Strategy for the Solar Supply Chain

The benefits of a US-based solar supply chain are clear. They include national security and energy security. The US needs a source of solar equipment it can rely on as our energy grid moves increasingly to solar power. Today, only some 5% of US energy comes from solar, but experts expect the share of US energy from renewables could reach as high as 50% by 2030. Renewables include wind and biofuels, as well as solar, but solar holds out the most promise of cost reduction over the long term because of the opportunity for technological breakthroughs in the industry. Today a solar cell only turns some 24% of the light that hits it into electricity. The increasing efficiency of solar cells, combined with breakthroughs in energy storage (batteries) is set to let solar power take a much larger share of our energy supply.

A further important issue is the synergy between solar manufacturing and semiconductor manufacturing. Both use polysilicon as the key input. Today, some 70% of the polysilicon manufactured globally goes into solar cells and the remaining 30% into semiconductors. If the US intends to remain a major player in either industry, we must be a big player in both industries. Allowing China to monopolize polysilicon presents dangers not only to a US solar industry, but to the US semiconductor industry as well.

A further advantage of a domestic manufacturing industry is that it creates other jobs among suppliers of both goods and services. For example, in November 2020, Japanese global glass manufacturer NSG Group opened a 500,000 square foot facility in Troy Township, Ohio to supply First Solar's state-of-the-art manufacturing facility in nearby Perrysburg, Ohio. The glass plant, the first new float glass plant in the US in 40 years, employs 150 workers and can produce up to 600 tons of glass a day. It's estimated that the typical manufacturing job creates three additional jobs among suppliers.

We must also consider the direct economic benefits of manufacturing to workers. The manufacturing sector is the only major segment of the economy that can deliver high and rising wages to a large section of the working population. That's because only manufacturing can deliver steady, significant increases in productivity year after year. Unlike R&D work, manufacturing does not require high levels of education. It requires skills, aptitudes and dedication that the average working man or woman can learn. Historian Yuval Noah Harari points out that in the Middle Ages the average farmhand was able to harvest five bushels of wheat a day. In 2014, a combine harvester set a record by harvesting 30,000 bushels in a day. That is a 6,000-fold improvement over 600 years, applied to a manual process. There is debate about how much workers have shared in recent years in the benefits of productivity improvements, but there is no doubt that they gain some improvement in real wages.

Solar installation, the dominant type of work in today's import-dependent US industry, is a perfectly good job (although clambering around on roofs brings with it certain risks). But by the nature of installation work, it can never deliver the sort of constant productivity improvement that a manufacturing job can. Manufacturing jobs pay better, and include better benefits, than installer work.

We can illustrate this difference with industry data. According to BLS data for May 2019 (date of the latest available occupational survey), the average manufacturing employee earned 22% more than the average solar installer, assuming both employees worked a full 40-hour week throughout the year. Of course, most solar installers do not work 52 weeks a year. It's likely that in a typical year, a manufacturing employee in a solar facility would earn 50% to 100% more than a solar installer.

Table 1: Solar pay scales compared

Occupation	Average Hourly Wage	Average Annual Pay(*)	Uplift compared to Installer
Solar Photovoltaic Installer	$ 22.52	$ 46,850	
Manufacturing Employee	$ 27.58	$ 57,366	22.4%

(*) Data from May 2019 survey; Annual data assumes 40 hr work week and 52 weeks per year

Source: US Bureau of Labor Statistics

In 40 trips to China and many trips around the US and Europe, Frank van Mierlo has visited most of the world's solar factories. He had this to say about US manufacturing: "The First Solar factory in Ohio is arguably the best solar facility on the planet. It's high tech, completely automated, it has a low carbon footprint and high productivity. And when you think about the 100 US solar companies that were killed off in the years of China's solar offensive [2012-2014], it's a sobering reality that a number of those companies had the potential to be additional First Solars."

Policy Recommendations

With annual consumption exceeding 20 GW a year, the US can and must have its own end-to-end solar supply chain. The federal government should adopt policies that can achieve this objective and sustain it in the face of the predatory practices of China. Those predatory practices, in existence for more than a decade, are set to become more intense in the next several years. US policy should not be based on investigating and then "punishing" Chinese companies for specific unlawful practices; that is an approach that only creates work for lawyers and usually only delivers benefits, if at all, when the US victim companies are at death's door. Instead, our policies should be aimed at creating an end-to-end US solar industry targeting at least 50% of the market in each segment of the supply chain.

Policies to be urgently considered include:

- **A "Made-in-USA solar tax credit" available to US-based solar manufacturers based on the US value-added in their product and their annual sales.** The solar investment tax credit of 26% is a successful program that received bipartisan support in December's congressional vote. A made-in-USA solar tax credit should be initiated as a separate program at the same order of magnitude as the ITC in terms of total cost. According to one Congressional report, the solar ITC costs the Treasury around $2.7 billion a year. If we added a made-in-USA tax credit on a similar scale, we would still be supporting our solar industry at a fraction of the level by which China supports its solar industry. The tax credit would include polysilicon manufacturing, ingot/wafer production, as well as solar cell and module manufacturing. Such a tax credit would save existing polysilicon jobs in Washington, Michigan, and Tennessee, and lead to the creation of new jobs in new manufacturing locations.
- **Strengthened Buy American policies requiring the federal government to buy only US-made solar equipment AND power generated only from US-made solar equipment.** Today's Buy American laws are more notable for their loopholes than their effectiveness. Some federal agencies do favor American solar modules but many more, including even US military bases, exploit loopholes to buy imported equipment or to buy power generated by imported solar equipment. Congress should pass beefed-up requirements that make the US government and all its agencies the lead customer for made-in-USA solar equipment, again using a value-added standard rather than one focused solely on the final assembly of the module. Recognizing China's objectives in strangling foreign competition, the upstream segments of the industry are just as important as solar module assembly, and made-in-USA preference should include that objective.
- **Ban products made with Xinjiang forced labor.** US workers should not be competing with slave labor. The US consumer should not be supporting forced labor with his or her pocketbook. And US taxpayers should not be supporting forced labor with their tax credits. This is a human rights issue and an economic rights issue. Congress must pass a tough law citing Xinjiang solar inputs and final products as high priority banned imports as soon as possible, and institute an auditing process to gain as much visibility as possible into the manufacturing location of the materials and components of all imported solar equipment. Many solar modules imported from Malaysia and Vietnam likely contain Xinjiang poly, so country of final shipment is not a reliable guide.
- **Persistent, long-term tariffs on all inputs in the solar supply chain.** We must recognize that however strict we attempt to make our restrictions on Xinjiang products, China will still succeed in bringing in goods linked to their forced-labor economy. To enable businesses to plan with reliability and to enforce US standards of human rights that prohibit US dollars supporting forced labor, we must implement persistent, long-term tariffs on imports of all solar inputs and products, from polysilicon through to modules. In light of China's ability to subsidize artificially low prices, a persistent tariff of 50% might be needed to guarantee a growing, self-sufficient US solar supply chain.
- **Dedicated federal research & development support.** The US should increase financial support dedicated to the solar industry, including manufacturing as well as fundamental research. Process is as important as product and both should be supported. Increased

federal support for key technologies is already envisaged in the Endless Frontiers bill now before Congress.

- **Increased support for STEM education.** The US has fallen behind many other nations in STEM education. The fundamental driver of US technological progress is the quality and quantity of graduates coming through our universities with education in these vital areas. We must increase the number of Americans choosing to study STEM subjects. The best way to do this is with federally-supported scholarships that make it clear that these subjects are more valuable to the nation than other subjects because of their importance to national and economic security. We must also reduce the number of Chinese students, especially graduate students, in these courses. Unfortunately, there is a high incidence of spying by Chinese students, orchestrated by organs of the Chinese government. A recent study by Georgetown University found that 16% of US STEM graduate students are Chinese. Innovation is what creates the manufacturing jobs and puts the products on an ever-decreasing cost curve that is ultimately more effective than scale-driven me-too manufacturing as practiced in China.

This set of policies combines carrots and sticks: carrots to induce and incentivize the return of a US solar industry and sticks in the form of tariffs to keep out predatory, subsidized foreign imports, mostly from Chinese companies and some based on technology stolen from US companies in the first place.

These policies would accelerate the move to renewable energy, create tens of thousands of good jobs in many regions of the country that need an economic boost, and improve US resilience and self-sufficiency. They would encourage venture investors to support more solar technology startups, as they did in the 2000-2010 period, creating more good engineering and scientific jobs in technologies that will be vital for our future.

The common objection to such policies is that they will raise the price of solar installations in the US. But as Figure 3 above shows, the price of solar equipment and solar installations has continued to fall at a rate of 8%-10% a year despite the 2018 tariffs. Our recent experience with tariffs under President Trump has shown that as long as there is sufficient competition in the US market, tariffs have little effect on price levels, and what effect they do have tends to be temporary. We have documented these effects elsewhere. One simple example is that Trump's 2018 20% tariff on washing machines led to the BLS price index for laundry equipment (the category that includes washing machines) in 2019 to be just 0.8% above the level for 2016. Despite recent increases in the price of laundry equipment in 2020 due to shortages in cargo ships to bring in consumer durables from Asia, the laundry equipment price index has risen to 103.9, yet is still below 2013 levels.

More fundamentally, the US has learned that cheap goods from Asia are a poisoned chalice. The flood of cheap goods destroys good jobs and reduces living standards for thousands of workers, with corrosive follow-on effects as job losses and pay cuts reverberate through cities and states across the country. When all is said and done, the jobs and income cost of the cheap goods overwhelmingly outweighs the benefits.

Conclusion

The US solar power manufacturing industry is in the early stages of a renaissance, clearly visible in the surging production of solar modules in the US. However, China continues to raise the stakes, with bigger, more aggressive targets and subsidies for the Chinese solar industry. The US must take action to reinforce our own solar industry, embracing the full US solar supply chain including tariffs on subsidized imports. Renewable energy is too important an industry to allow one hostile, undemocratic nation to monopolize the supply of the equipment to produce this vital resource.