Catalyzing American Solar Manufacturing

A roadmap to achieving 50 GW of domestic solar manufacturing capacity by 2030

SEIA Solar Energy Industries Association®

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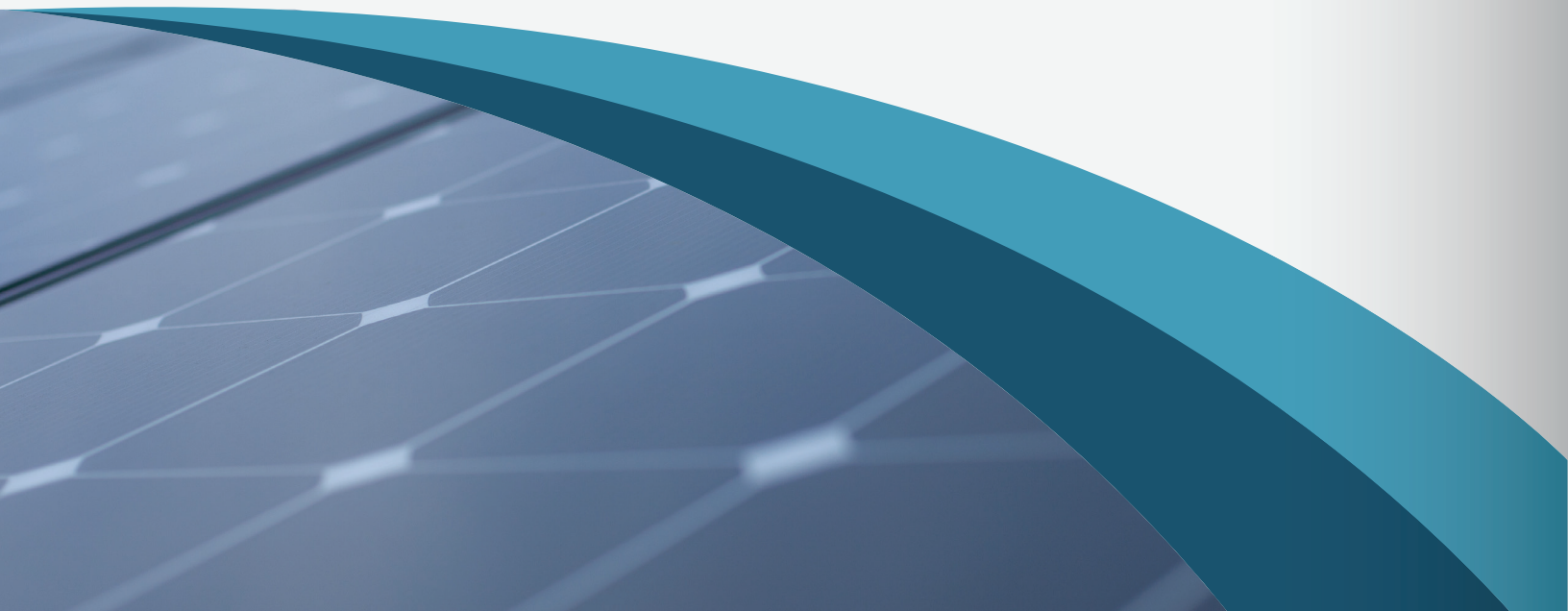

Executive Summary

If America is to reach its climate goals, our country must achieve solar deployment targets like those envisioned in the Solar+ Decade, where solar will account for 30% of all U.S. electricity generation by 2030. Achieving this target will require a strong U.S. solar manufacturing base, which is also critical to preserving economic and national security. In this roadmap, you will read how policy, supply chain factors, international trade, economic growth and environmental and climate concerns can drive a revitalization of an American solar supply chain. This roadmap is the first report in a series of papers that will focus on emerging opportunities and challenges for the solar and storage industry. The next report will focus on building a robust U.S. manufacturing base for energy storage equipment.

The recently passed Inflation Reduction Act (IRA) includes important incentives that will, over time, lead to a renaissance in American solar manufacturing. The IRA adopts a holistic approach and includes a suite of policy options focused on long-term demand drivers, investments in new manufacturing facilities and equipment and ongoing domestic production support as new facilities come online and scale operations.

As a direct result of the IRA, we expect to see significant new investments in domestic solar module, tracker, inverter and racking capacity within the next 2-3 years, followed by new investments in solar ingot, wafer and cell capacity within 3-5 years. By the end of the decade, the IRA will be instrumental in ensuring the U.S. solar industry meets its goal of 50 gigawatts (GW) of domestic solar manufacturing capacity across all key industry segments by 2030.

Meeting these expectations, however, will not be easy. It will require demand certainty, strategically planned investments in new manufacturing capacity at scale and avoiding a multitude of pitfalls that could unnecessarily hinder growth. For example, America currently has no domestic solar ingot, wafer, or cell manufacturing capacity and only modest capacity to produce solar modules, inverters and trackers. A balanced trade policy will therefore be essential to ensure that imports continue to play an important role in the U.S. market until domestic manufacturing is ready to fill the void.

We must also recognize the essential role of state economic development investments in driving new domestic manufacturing capacity and the important opportunity to leverage new manufacturing investments to advance diversity, equity, inclusion and environmental justice.

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Introduction

The U.S. solar industry has faced a variety of supply chain and policy challenges in recent years, some of which significantly reduced solar deployment. While our country can overcome these challenges, we must keep two important lessons in mind. One, the United States will continue to face barriers in meeting its full solar potential without a robust domestic solar manufacturing base. And two, the country's overreliance on solar imports is an economic and national security vulnerability.

Indeed, in taking extraordinary measures under the Defense Production Act recently, the Biden administration concluded that "action to expand the domestic production capability for solar photovoltaic modules and module components is necessary to avert an industrial resource or critical technology item shortfall that would severely impair national defense capability."[1] It is essential to the nation's continued economic health, global competitiveness and energy security to quickly address our overdependence on solar imports and lay the foundation for a robust solar manufacturing base here in America.

As the U.S. Department of Energy (DOE) recognized earlier this year, "[g]reatly 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."[2] DOE also recognized that the United States will not be able meet its climate goals without significantly expanding domestic clean energy manufacturing, and solar manufacturing in particular.[3] But with the right federal investments, DOE concludes that domestic solar module production capacity could reach 10 GW in two years, 15 GW in three years and 25 GW in five years.[4]

Achieving these goals, however, will require a balanced manufacturing and trade policy. In particular, new tariffs on imported solar cells, which are not likely to be widely produced in the United States for years, would undermine efforts to build out domestic module production capacity. History shows that tariffs in general have not had the desired effect of adding U.S. manufacturing capacity. Instead, they have limited U.S. solar deployment, which has reduced the likelihood of investments in domestic manufacturing.

The Biden administration took an important step in June to pause any new circumvention tariffs on imports from Cambodia, Malaysia, Thailand and Vietnam for two years. Just the threat of these tariffs froze solar supply chains, and the president's action gave the market some breathing room.[5]

[1] Memorandum on Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as amended, on Solar Photovoltaic Modules and Module Components (June 6, 2022).

[2] Fact Sheet: Achieving American Leadership in the Solar Photovoltaics Supply Chain, U.S. Department of Energy, DOE/OP-0012-1 (February 24, 2022).

[3] Id.

[4] Secure the Supply Chain for a Robust Clean Energy Transition, U.S. Department of Energy Response to Executive Order 14017, America's Supply Chains (Feb. 22, 2022).

[5] Although the President implemented a two-year moratorium on potential tariffs, a positive determination by the U.S. Commerce Department in the pending anticircumvention investigation would still be contrary to existing precedent and harmful to both solar deployment and domestic manufacturing.

It is essential to the nation's continued economic health, global competitiveness and energy security to quickly address our overdependence on solar imports and lay the foundation for a robust solar manufacturing base here in America

It is well documented that federal industrial policies can launch massive private sector investments. In referencing multiple research studies, the U.S. Department of Energy (DOE) has concluded that:

> policies and practices such as heavily subsidizing manufacturing and associated supply chains; streamlining siting and permitting; investing in necessary infrastructure; creating workforce education and training programs; and ensuring procurement with environmental conditions that preference their own domestic manufacturers have encouraged the development of in situ manufacturing needed to support the energy sector.[6]

To date, federal solar policy in the United States has focused on incentivizing solar deployment. However, with passage of the IRA, the United States broadened its federal incentive program to include domestic manufacturing through new tax credits, grants, low-cost loans, government procurement, research and development support and public-private partnerships.

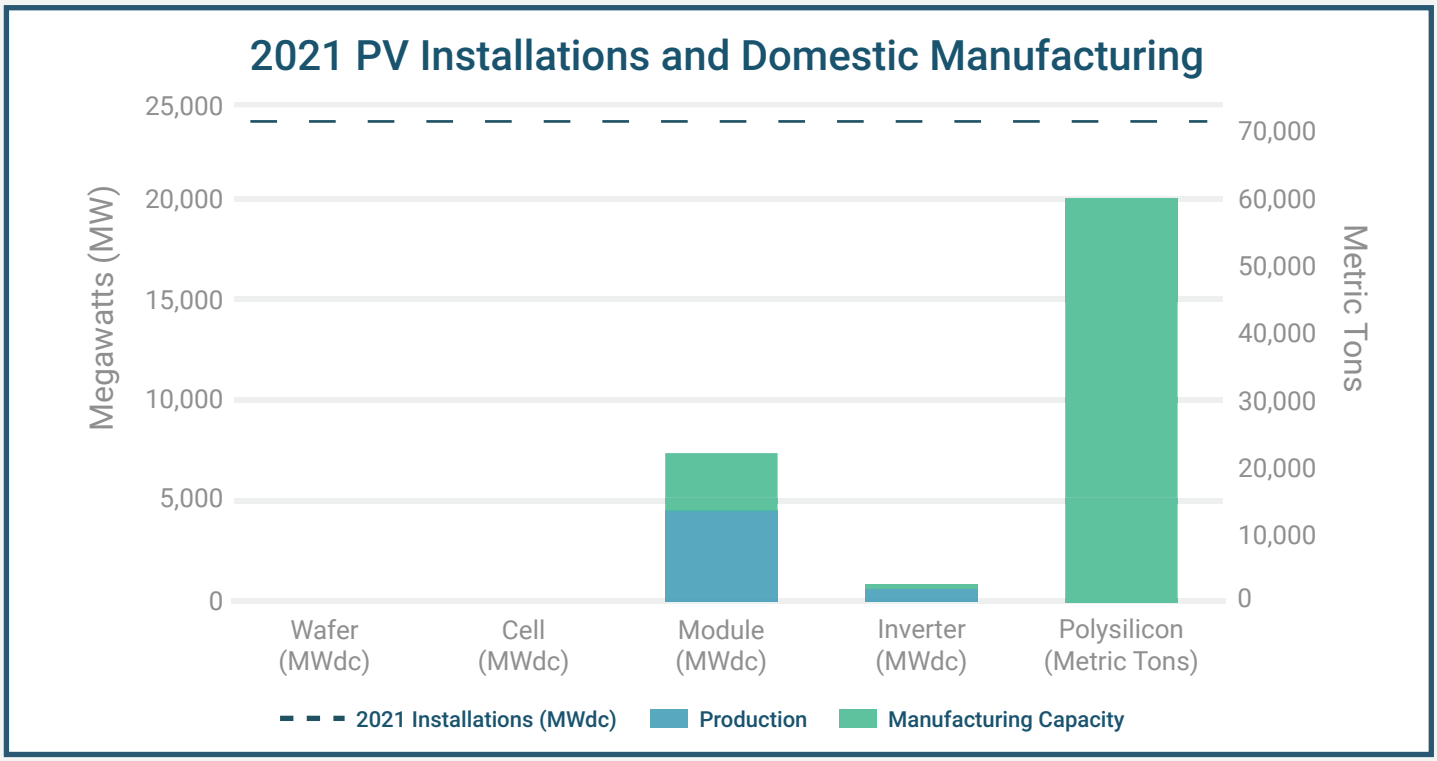
The IRA has the potential to greatly expand solar and storage manufacturing in the United States. These incentives, however, must be deployed strategically. What works for one segment of the supply chain may not be appropriate for other segments.

The timing of investments must also be taken into consideration. For example, rapidly scaling solar ingot and wafer operations before new domestic cell capacity comes online could potentially strand new investments, particularly in the absence of export opportunities. The importance of domestic raw material supplies, and funding for related environmental impact assessments also cannot be overlooked. For example, building new domestic solar glass capacity will significantly improve the cost competitiveness of U.S. module assembly.

[6]Secure the Supply Chain for a Robust Clean Energy Transition, U.S. Department of Energy Response to Executive Order 14017, America's Supply Chains (Feb. 22, 2022).

Current Domestic Manufacturing Capacity

The United States currently has capacity to produce metallurgical grade silicon, polysilicon, steel, aluminum, resins, racking and mountings and other key materials. But significant gaps in the U.S. solar supply chain remain. For example, the United States currently has no domestic solar ingot, wafer or cell manufacturing capacity and only modest capacity to produce solar modules, inverters and trackers.[7] There are also limited U.S. resources for solar specialty glass; with only three glass manufacturers identified in the U.S.[8] It is important to not only fill in these gaps but help expand and improve the competitiveness of existing manufacturing capacity, e.g., new investments in existing polysilicon capacity are necessary to bring mothballed facilities online and improve the competitiveness of U.S. polysilicon production.



Timelines for New Capacity Additions

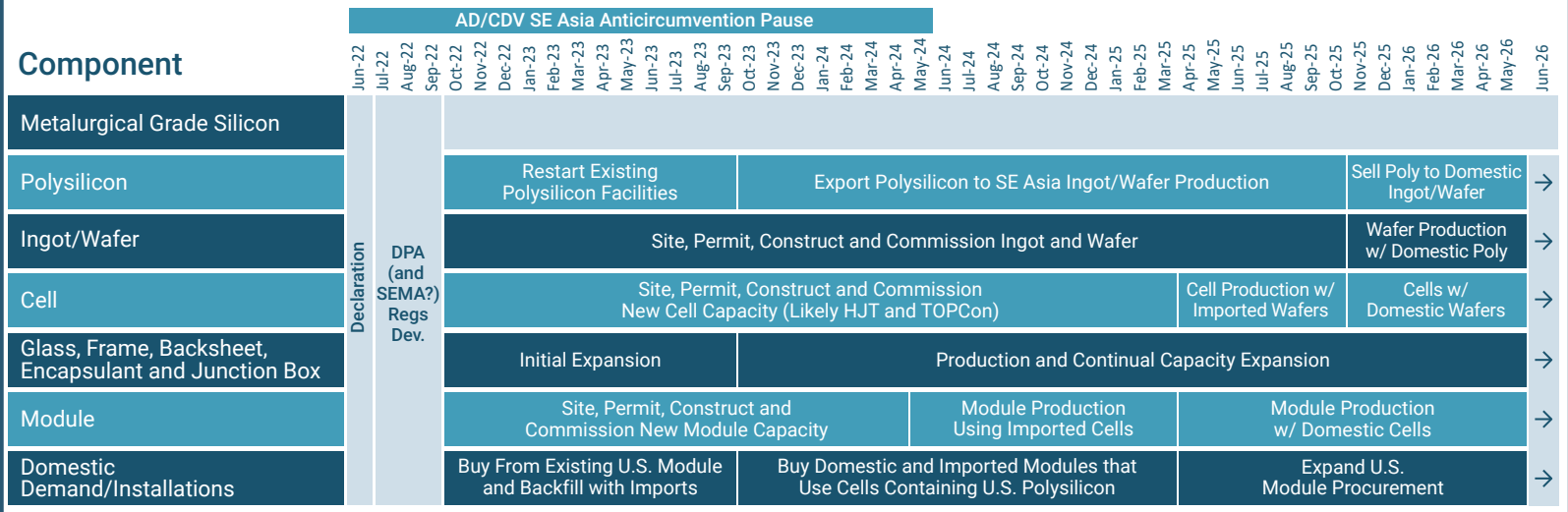
In June 2021, SEIA set a goal of 50 GW of U.S. solar manufacturing capacity by 2030 for each of the following key segments: polysilicon, wafers, cells, modules, inverters and trackers.[7] With the right application of new IRA incentives, the United States should meet, or even exceed, this 50 GW goal. There are, however, practical timelines for siting, permitting, constructing and commissioning new factories that influence how quickly domestic manufacturing can scale.

[7] It should be noted that there have been recent investments in some elements of domestic tracker manufacturing capacity, e.g., torque tubes. In contrast, other tracker inputs such as actuators continue to be mainly produced overseas.

[8] Solar Materials | Crystalline Panel Process | Glass | Glass Manufacturers, ENF Solar, https://www.enfsolar.com/directory/material/glass, accessed August 15, 2022.

Set forth below is a Gantt chart outlining the practical timelines for adding new solar manufacturing capacity in the United States.

Gantt Chart: Primary Solar Module Component Siting, Permitting and Construction Timelines[9]



The above timelines reflect estimates for existing manufacturers who have a proven, calibrated manufacturing process (or process of record) that can be replicated at a new factory. In contrast, companies new to the manufacturing space or those looking to establish new manufacturing processes will likely require at least an additional 12 to 18 months for vetting equipment suppliers, engineering factories and demonstrating their ability to perform. These new entrants will also require time to commission, calibrate and refine their new manufacturing processes. Additionally, given its current reliance on imports for nearly all elements of the solar supply chain, U.S. facilities will initially have longer lead times versus facilities in other countries where supply chains are more established.

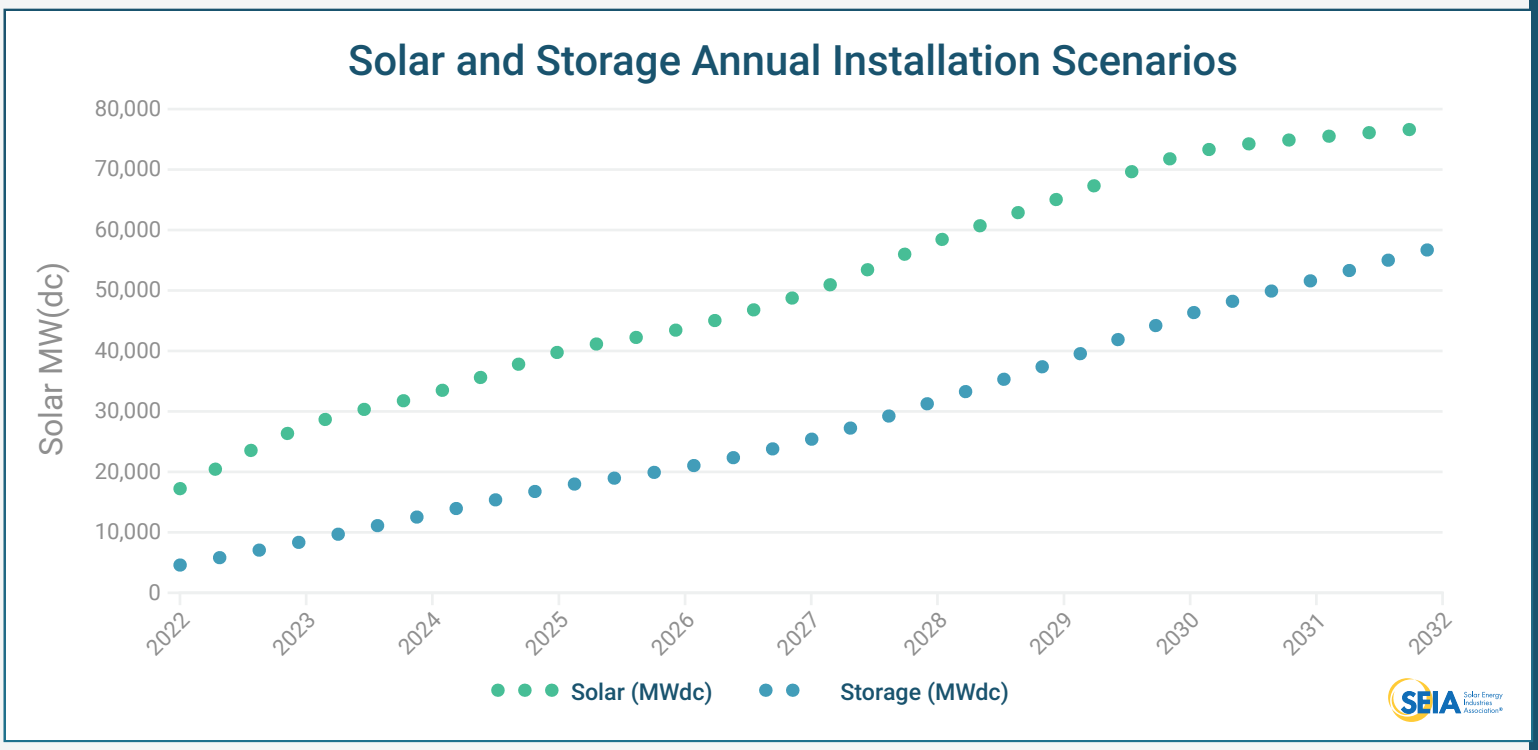
The Importance of Demand Outlook

Before committing to new U.S. manufacturing investments, companies need reasonable assurances that there will be sufficient demand for their products. Initially, factories built in the United States will primarily serve domestic markets with exports as a secondary consideration.

Companies will first look to U.S. installation forecasts to see if there will be sufficient demand for their products at the time a prospective factory would become operational. They will also look beyond that operational date to fully amortize the capital cost to build the factory. For example, if a factory takes four years to become operational from the date of initial planning and an additional five years to operate at a high utilization rate and amortize costs, the manufacturer will need assurances that U.S. demand for their products will be strong from mid-2026 through mid-2031.

[9] Solar Photovo--ltaics: Supply Chain Deep Dive Assessment, U.S. Department of Energy (February 2022); Exawatt analysis prepared for the Solar Energy Industries Association (March 2022).

Fortunately, the IRA includes a long-term extension of the solar Investment Tax Credit which will serve as a strong demand driver. Below is a forecast of U.S. solar and storage demand based on adoption of the IRA. This forecast demonstrates that a long-term extension of the ITC is a critical demand driver and important precursor to a renaissance in domestic solar manufacturing.



Manufacturers must also consider the timing of demand for their products. For example, module, inverter, mounting system and tracker manufacturers can expect to see immediate demand for their products. In contrast, it will take time to build demand for other segments, such as ingots and wafers. It would therefore be suboptimal to complete a U.S. ingot/wafer factory before there is sufficient demand from domestic cell factories, as it is unlikely to be economical to export wafers while awaiting domestic demand.

A Downstream-to-Upstream Supply Chain Growth Strategy

Domestic manufacturers should focus on building downstream production first and backfilling components with imports while upstream domestic production is built out, as shown in the Gantt chart above. Building the supply chain in this way is the most efficient path forward, and the suite of policy options in the IRA should be implemented to support the right components in the right order. While scaling domestic module capacity will take 2-3 years, it will be 3-5 years before there is significant domestic manufacturing capacity for ingots, wafers and cells.

One notable exception to this strategy of building from the bottom of the supply chain up is the opportunity to recommission existing polysilicon factories in advance of any demand from domestic ingot/wafer factories. Mothballed U.S. polysilicon facilities previously served export markets and may be able to do so again given new ingot and wafer manufacturing capacity in Southeast Asia.

Shipping costs for polysilicon are not prohibitive, and shipping U.S. polysilicon to facilities in Southeast Asia may also ease compliance with product traceability requirements under the Uyghur Forced Labor Prevention Act. However, like other components, new investments in polysilicon capacity or factory upgrades will require demand certainty to justify private sector investments, particularly given the initial absence of demand for polysilicon in the United States.

Domestic manufacturers should focus on building downstream production first and backfilling components with imports while upstream domestic production is built out

Ensuring Domestic Production Can Compete on Cost

U.S. manufacturers must be able to offer in-demand products, sell at a competitive price and deliver consistently high-quality goods in sufficient quantities on time. For example, several overseas manufacturers individually have larger manufacturing capacities than the entire U.S. industry. This enables overseas suppliers to operate with economies of scale far beyond most U.S. facilities.

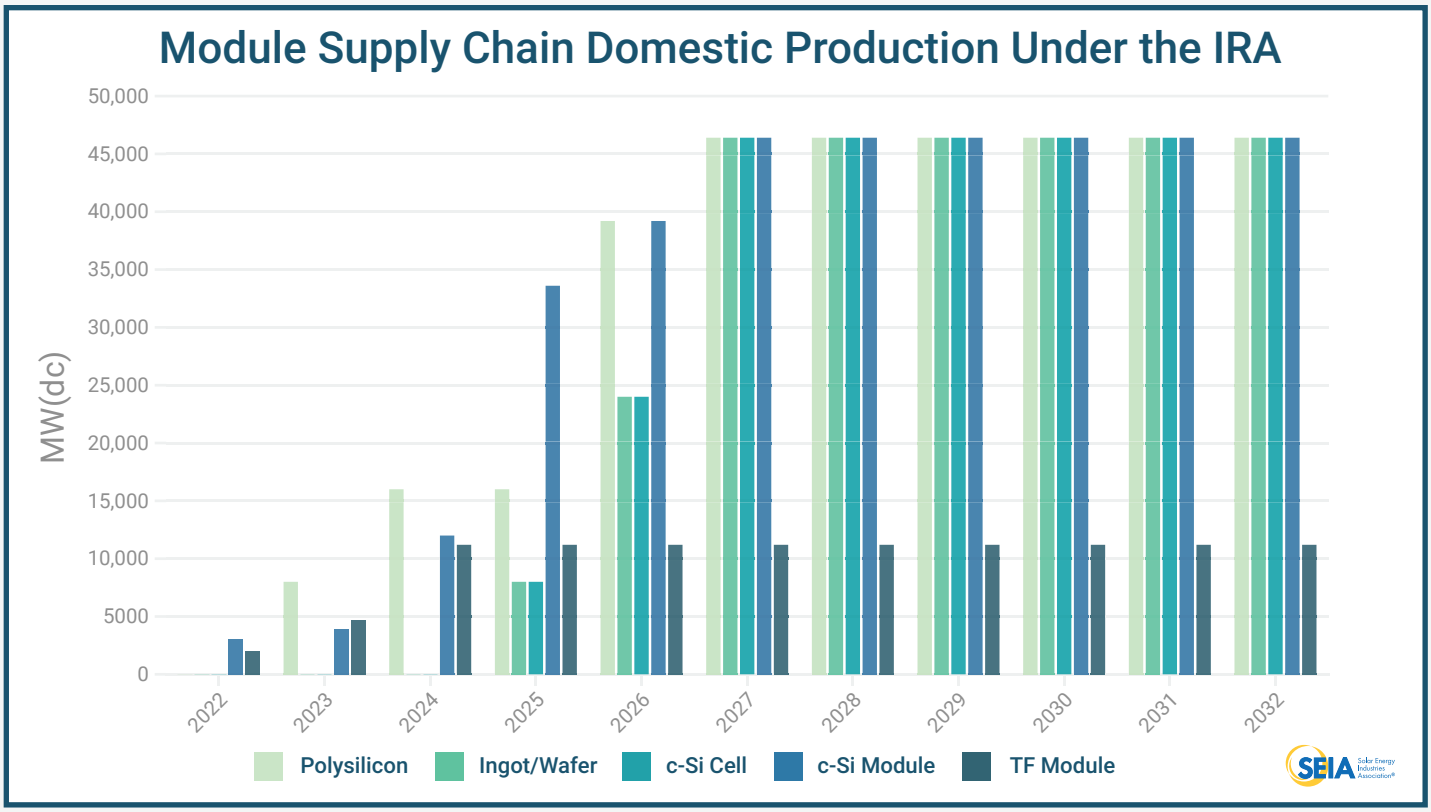
Manufacturing at scale is particularly important in the utility-scale segment where project developers require large volumes of products to be delivered over a relatively short period. Developers also avoid customer concentration risk, i.e., committing too high a percentage of a factory's output to a single order. As a general rule, a solar module manufacturer's capacity needs to be at least four times the size of a given project.

Reaching scale, however, takes large upfront investments and the ability to sustain higher production costs for an extended period of time. For these reasons, companies are reluctant to invest in U.S. manufacturing in the absence of long-term federal incentives, which competing governments currently provide to their solar manufacturers. In recognition of this challenge, the IRA includes the Solar Energy Manufacturing for America Act (SEMA), a long-term tax incentive for certain domestically produced components, and serving as a critically important driver of U.S. manufacturing.

Tax credits help both incentivize private sector investments in U.S. manufacturing capacity and close the cost gap between domestic production and imports. Indeed, the vast majority of manufacturers currently considering U.S. factories have made clear that they will only move forward with large U.S. manufacturing investments if tax credits are enacted, and, for some, likely only if there is a good way to monetize those credits, such as direct pay. Both of these requirements are satisfied in the IRA.

What's Achievable?

With the adoption of the IRA's climate provisions, including a long-term extension of ITC, manufacturing tax credits, manufacturing production credits and effective tax credit monetization, several module manufacturers are expected to move forward with domestic manufacturing plans. Groundbreakings for large-scale manufacturing facilities will likely commence in 2023, and the first new factories supported by these policies will begin production in 2025, or as early as 2024 for trackers, racking and aggressive inverter and module manufacturing investments. New module capacity assumes, however, the continued availability of cost competitive imported cells.



Materials Supply

The expansion of solar module manufacturing under the IRA is expected to lead to new investments in domestic manufacturing capacity for key material inputs, such as solar glass, junction boxes, frames and polymers. Localizing these materials will play a critical role in the long-term competitiveness of U.S. solar manufacturing. Capacity for these items could conceivably be built out faster than the primary solar components and, if produced at economic scale, would greatly improve the long-term cost competitiveness of domestic solar manufacturing. For example, the importation of solar glass and frames comes with shipping costs nearly as high as shipping costs for completed modules, pointing to a significant opportunity to reduce solar module costs through new domestic solar glass and frame manufacturing capacity.

In addition, even where there is existing U.S. supply for these materials, e.g., castings for tracker drive systems, it can be difficult for domestic suppliers to compete against lower-priced imports. A holistic approach to increasing the global competitiveness of the entire supply chain will therefore be essential. Ensuring competitive material supply is one area where the Defense Production Act could play a particularly important role.

Workforce Considerations

A U.S. solar manufacturing industry is dependent upon a well-trained workforce. Manufacturing not only brings opportunities for permanent and high wage jobs, but also the ability to help offset job losses in traditional energy and manufacturing communities. To meet this need, the industry must work as hard to develop the American solar workforce as it does on building new factories.

In the short term, commissioning new factories and training U.S. workers will require a supportive immigration policy and foreign-based manufacturing experts and engineers familiar with existing technologies. This is particularly true for solar ingot, wafer and cell manufacturing and is another reason that low-cost imported cells are necessary for the foreseeable future. Longer-term, U.S. solar manufacturing will require a readily available pool of production workers as well as solar-ready computer scientists, chemical engineers, electrical engineers, process engineers and more.

A successful American solar workforce depends upon collaboration between companies, government agencies and higher education institutions; to advance solar-specific technical training and college-to-career programs. For example, apprenticeship programs that provide professional development opportunities demonstrate that good manufacturing jobs are possible without a college degree. And while cross-sector partnerships will deliver results, government support will make a critical difference.

> ***The industry must work as hard to develop the American solar workforce as it does on building new factories***

Diversity, Equity, Inclusion and Justice (DEIJ)

Developing tomorrow's solar-ready manufacturing workforce provides an opportunity to build a more inclusive and just energy economy. Utilizing existing tools, such as supplier diversity databases, can ensure that the solar industry draws from a wide talent pool and engages all communities in the benefits of solar. The industry should develop and advance scholarship, curriculum and internship programs with Black-, Latino- and Indigenous-serving institutions and other organizations focused on DEIJ to create a diverse talent pipeline of solar-ready graduates. Similar programs already exist within the solar installation segment and must be expanded to include manufacturing.

The industry should also seek partnerships with unions and community groups to ensure equitable access to apprenticeships and other quality, skill-building programs. In addition, workforce development should address the gender imbalance in the solar industry, particularly manufacturing and engineering roles which have traditionally been dominated by men.

Environmental justice is another a critical consideration. The industry must minimize negative externalities in communities where manufacturing facilities are located and ensure that members of those communities are engaged and have a say in the siting and development of those facilities. Further, environmental responsibility should be incorporated in all aspects of the product lifecycle, from raw materials to end of life, with goals measured annually through environmental, social and governance reporting. Advancing carbon reduction strategies, pursuing technological diversity and reducing the use of critical minerals in the solar supply chain are also important objectives.

Incorporating DEIJ principles into the solar manufacturing base not only benefits individuals and communities, but garners meaningful support from external stakeholders. Acting now will help move the country towards a diverse and equitable solar industry which lives up to its full potential.

The Continued Importance of State Economic Development

State economic development agencies and the incentive packages they offer have been the primary drivers of U.S. solar manufacturing to date. State incentive packages reduce upfront costs, expedite timelines and offer tie-in opportunities for other goals. The scope and level of incentives vary based on a state's interest in a specific industry and other policy goals, but generally fall into three categories: (i) tax incentives; (ii) workforce development; and (iii) siting and permitting support. Coupling these state-level incentives with long-term federal investments will quickly make the United States a leading choice for solar manufacturing investments globally.

Conclusion

The United States doesn't have a choice. Whether today, tomorrow or years down the road, we must invest in domestic solar manufacturing. Our country's economic and national security depends on it. Fortunately, the IRA recognizes the urgency of the moment with a transformative suite of federal investments in solar manufacturing. These investments must be deployed strategically and with a recognition that transitioning from imports to domestic manufacturing will take time. Congress and the Biden administration provided the tools necessary to build a robust domestic solar manufacturing base. It is now time for the U.S. solar industry and its partners to use these tools wisely and seize the promise of American solar manufacturing.

Appendix: Pitfalls to Avoid

1. **Failing to go big:**
   - The United States requires a core group of mega-factories able to compete globally. Small factories should focus on niche markets.
   - Setting aside economies of scale, utility-scale developers need suppliers with capacities at least four times their project size. For someone building a 350 megawatt (MW) solar power plant, that means at least 1.4 GW of USP module capacity.
2. **Building out the supply chain in the wrong order.**
3. **Building factories dependent on obsolete production equipment, or that are dependent on obsolete or soon to be obsolete technology (efficiency and automation are key to producing cost-effective and quality products).**
4. **Only incentivizing capital expenditures (CapEx):**
   - CapEx is an important hurdle, but it is only a fraction of a product's cost when considered over long-term horizon (polysilicon is an exception).
5. **Federal tax incentives that are difficult to monetize, particularly for domestic manufacturers. Tax credit policy should include a way to facilitate monetization.**
6. **Only paying attention to high-tech components or end products:**
   - Solar manufacturing is not just module manufacturing.
   - There are many components critical to a solar project and many inputs critical to a component.
7. **Not providing long-term investments focused on demand certainty, CapEx support and ongoing production support.**
8. **Targeting technologies that are not commercially ready:**
   - Need to focus on building leading-edge technologies commercially available for when factories come online. For crystalline silicon wafers, that means larger wafer formats. For solar cells and modules, this likely means heterojunction and TOPCon.
   - Essential to continue research and demonstration for more advanced technologies, but companies should not focus large-scale manufacturing on unproven technologies.
9. **Other issues to avoid:**
   - Failure to consider building and siting challenges, e.g., permitting, access to roads, electricity access, etc. There are parallels between building a factory and the challenges in building utility-scale solar projects around land use and environmental impact. For example, it should not be assumed that everyone wants to see a new factory in their area or that they know what goes on in a factory.

About SEIA

The Solar Energy Industries Association® (SEIA) is leading the transformation to a clean energy economy, creating the framework for solar to achieve 30% of U.S. electricity generation by 2030. SEIA works with its 1,000 member companies and other strategic partners to fight for policies that create jobs in every community and shape fair market rules that promote competition and the growth of reliable, low-cost solar power. Founded in 1974, SEIA is the national trade association for the solar and solar + storage industries, building a comprehensive vision for the Solar+ Decade through research, education and advocacy.

Learn more about SEIA's vision for American solar manufacturing at **seia.org/manufacturing**