THE STATE OF CLEAN ENERGY MANUFACTURING

AMERICA BUILDS POWER

AMERICAN CLEAN POWER

ACP sincerely thanks its member companies and other organizations for their contributions to the industry data provided in this report. ACP strives to provide the best information on the clean power industry—for the industry and by the industry—and therefore welcomes your comments.

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EXECUTIVE SUMMARY

Clean Power is Leading the American Manufacturing Renaissance

American clean power is leading a manufacturing renaissance across the country. Solar cells and modules made in Ohio, manufactured steel in New Mexico, advanced batteries in West Virginia, offshore service vessels built in Louisiana, and wind turbine blades in Iowa are just a few examples of the output from the 200 manufacturing facilities actively building primary clean power components to supply booming U.S. demand for new energy.[1,2]

Driven by unprecedented energy demand growth (ACP expects electricity demand to increase up to 50% by 2040), a rising focus on supply chain security, and a suite of targeted Federal energy tax credits, the nationwide onshoring of clean power production is creating 122,000 good-paying American jobs and generates $33 billion in annual domestic spending. These investments are concentrated in rural communities and 73% of active facilities are in Republican states. With a stable Federal trade and tax environment for the $141 billion in announced investment, clean power will be the foundation for American energy dominance that is built by Americans for Americans.

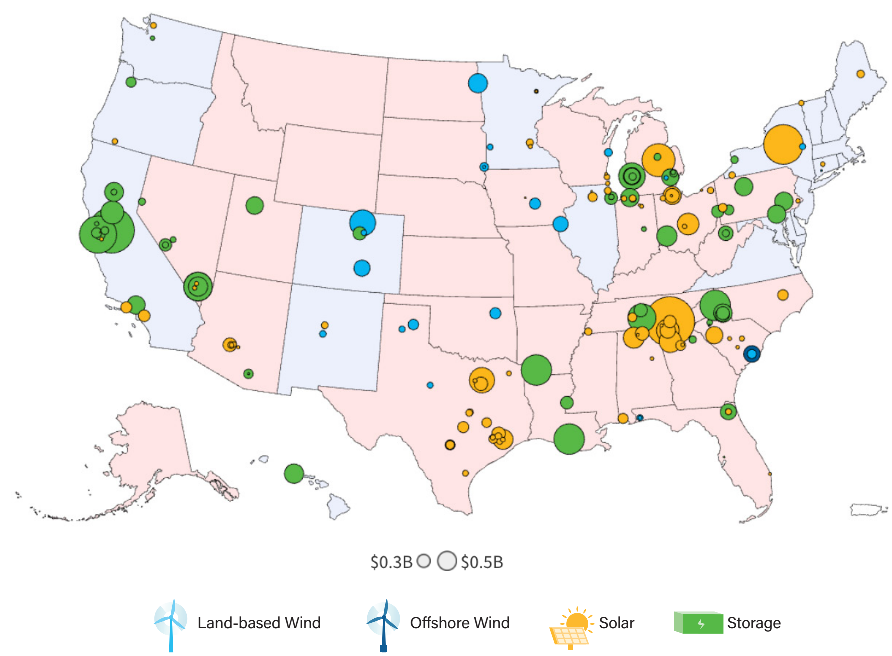
Current U.S. Clean Power Manufacturing Footprint

As of early 2025, the clean power manufacturing sector, specifically battery storage, wind and utility-scale solar, spans 200 primary manufacturing plants spread across 38 states, with notable clusters in the Southeast, Midwest, and Texas (Figure ES1). The breakdown of currently operational primary component facilities is as follows:

- **Solar:** over 90 manufacturing facilities
- **Land-based wind:** over 20 manufacturing facilities
- **Offshore wind:** over 15 manufacturing facilities
- **Battery Storage:** over 65 manufacturing facilities

In 2024 alone, the industry added 45 new facilities, marking a 45% increase from the previous year. These 200 primary component manufacturing facilities are attracting upstream and subcomponent suppliers to the U.S., providing new industry opportunities for existing domestic manufacturers. All told, there are well over 800 manufacturing plants contributing to the U.S. clean energy supply chain, with at least one in every state.

Figure ES1: Online Utility-Scale Solar, Wind and Battery Energy Storage System Component Manufacturing Facilities



1 ACP categorizes manufacturing "facilities" or "plants" as any unique manufacturing production line or expansion. There can be multiple "facilities" at one manufacturing location as they produce different clean energy components.

2 Primary components are defined in Table A1

Economic and Job Creation Impact

Clean power manufacturing currently supports 122,000 U.S. full-time jobs and generates $9 billion in domestic earnings annually (Figure ES2). The sector contributes $18 billion to Gross Domestic Product (GDP) and $33 billion in spending across the economy annually.[3]

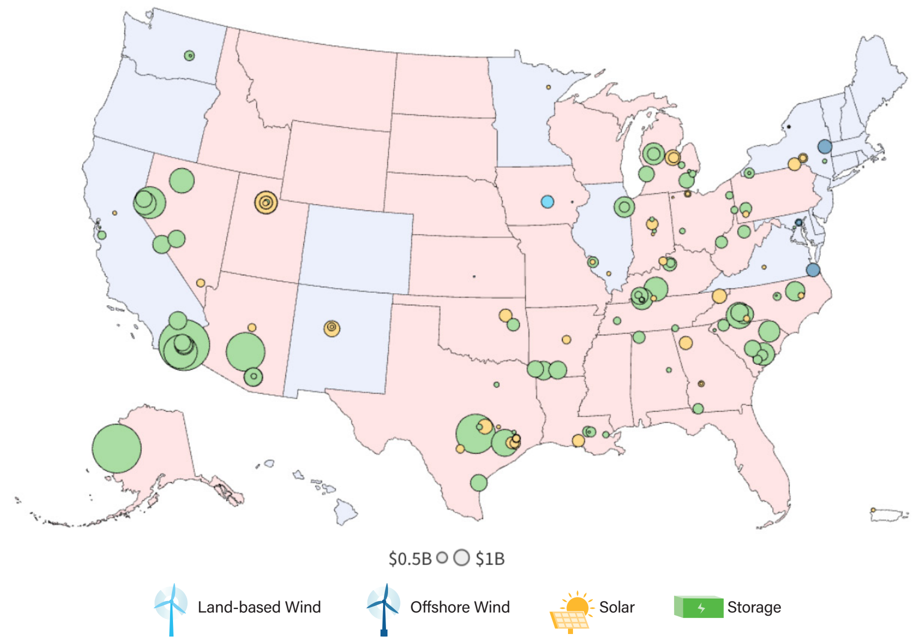
- **Solar:** 75,400 jobs, $5.9 billion in earnings, $11.5 billion in GDP
- **Land-Based Wind:** 34,300 jobs, $2.4 billion in earnings, $4.6 billion in GDP
- **Offshore Wind:** 700 jobs, $49 million in earnings, $90 million in GDP
- **Battery Storage:** 11,400 jobs, $800 million in earnings, $1.6 billion in GDP

The construction of these manufacturing facilities also supported the economy. Since August 2022, they required 343,000 job-years, generated $25 billion in earnings, contributed $37 billion to GDP, and incentivized $67 billion in spending.

Figure ES2: Annual Economic Impact Summary

	Jobs	Earnings	GDP	Economic Output
Operating facilities generate...	122,000	$9 billion	$18 billion	$33 billion
By 2030, operating and planned facilities could support...	579,000	$42 billion	$86 billion	$164 billion

Figure ES3: Domestic Utility-Scale Solar, Wind and BESS Manufacturing Project Pipeline[4,5]



The Promising Future for U.S. Clean Power Manufacturing

Since August 2022, the industry has announced 250 new manufacturing facilities or expansion, of which 140 are online or under construction, the remaining are under development (Figure ES3). Battery storage and solar components account for 230 of these new or announced facilities. If all planned facilities become operational by 2030, clean power manufacturing could support over 500,000 jobs, generate over $40 billion in earnings, contribute $86 billion to GDP, and add $164 billion in output to the economy annually.

3 For the purpose of this report, these terms have the following general definitions: (1) Jobs or employment mean job-years, and a full-time equivalent (FTE) job is 2080 hours per year; (2) Earnings are compensation of employees plus the net earnings of sole proprietors and partnerships excluding personal contributions to social insurance programs and employee pension plans; (3) GDP or gross domestic product, also referred to as value-added, is the market value of final goods and services produced in an economy; and (4) Output is the total market value of industry sales, which is equal to GDP plus intermediate inputs.

4 Pipeline is taken to mean projects across solar, wind and batteries that have been announced or are under construction.

5 Seven additional facilities have not yet announced locations: U.S. Forged Rings, VRB Energy, Phono Solar, Navitas Solar, Nexwafe, NuVision Solar, and DYCM Power.

ADVANCING CLEAN ENERGY SUPPLY CHAIN SECURITY: POLICY PRIORITIES

U.S. clean power is primed to lead a revitalized, modern American manufacturing sector well into the next decade, but maintaining the momentum will require sustained policy stability. Downstream product manufacturing—such as solar modules, battery cells and wind nacelles—have expanded swiftly and are attracting follow-on investments in midstream and upstream segments like solar cells, lithium processing and other manufacturing inputs. A renewed commitment towards key Federal clean energy programs and stable, strategic trade policy ensures manufacturing businesses continue executing on ambitious reshoring plans, investing in local communities and hiring hundreds of thousands of American workers.

The Trump Administration and Congress can build on their historic American manufacturing legacy with a suite of targeted policy tools that include:

- **Preserving Energy Tax Credits (45X, 45Y, 48C, 48E):** The Advanced Manufacturing and Technology-Neutral tax credits for solar, wind and energy storage have been the critical driver for the $33 billion of annual domestic spending and 122,000 jobs generated by new domestic clean energy manufacturing. The Advanced Manufacturing Production Tax Credit ("45X") creates critical long-term investment security for domestic manufacturers to compete against foreign-sourced products. The Technology-Neutral Investment and Production Tax Credits ("ITC/PTC") ensure that domestically built energy products have an attractive domestic market to sell into, with supplemental policies like the domestic content bonus adder further supporting the use of U.S.-made goods.
- **Creating a Stable and Strategic Trade Environment**: Trade policy must facilitate market stability. Tariffs require a strategic approach with clear timelines to allow continued certainty for American businesses and the economy. When tariffs are used to counter unfair trade practices, they must be phased in over time and be sector-specific to avoid inadvertently raising costs and suppressing demand for American businesses, including domestic manufacturers. Equally important is the strategic expansion of international supply partnerships—with allies that meet high labor and environmental standards—to diversify sourcing and reduce exposure to geopolitical risks.
- **Facilitating a True All-of-the Above Energy Strategy:** Energy demand from artificial intelligence (AI), data centers and domestic manufacturing will create skyrocketing energy demand. ACP estimates that the U.S. will require up to 50% more power on the grid in the next 15 years. Traditional energy sources, while necessary, are not enough to meet near-term needs. Solar, wind and energy storage are immediately available and will ensure that the cost of U.S. energy—including costs for energy-intensive domestic manufacturing processes—remains low and support the overall competitiveness of American manufacturers and businesses.
- **Streamlining Permitting will Benefit Domestic Manufacturers and their Customers:** Permitting reform remains a barrier to timely project deployment, including both new manufacturing and material processing facilities and new clean energy deployments using domestically made products. The Administration and Congress should establish clear, predictable, standardized permitting timelines across agencies and technologies, streamline permitting processes, align judicial review requirements (e.g., FAST-41) for manufacturing and energy projects with other sectors, and expedite high-impact transmission projects.
- **Ensuring Executive Orders on Energy and Critical Minerals Security Appropriately Leverage Demand from Downstream Manufacturers:** Key critical minerals required for national security and advanced military equipment require diverse end markets for commercial scale and viability. Supporting robust deployments of grid-scale clean power and domestic manufacturing creates crucial private, commercial opportunities for domestic processors of key minerals like graphite, lithium, indium and tellurium. This reduces the government's cost of maintaining secure supply chains. Utilizing policy tools like the Defense Production Act while maintaining stable clean power deployments can facilitate private industry efforts to boost the purchase of qualified domestically sourced or processed critical minerals.

The U.S. clean power industry is building a more secure, more competitive and more American energy landscape, through flexible, resilient and affordable solar, wind and energy storage meeting surging demand with products built in domestic manufacturing facilities. With bold leadership, the U.S. can continue unleashing American energy dominance by necessarily harnessing and supercharging clean power's incredible domestic scale and strength.

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INTRODUCTION

After decades of decline, U.S. manufacturing is growing again, driven by a historic wave of investment in clean energy technologies like wind, solar, and battery storage. Clean energy is no longer just a climate solution. It is a jobs engine, an economic strategy, and a national security priority.

In 2024, solar and wind energy made up 17% of the nation's power generation —surpassing coal for the first time (Figure 1). Clean power is now the most cost-effective way to meet surging electricity demand, and the shift is accelerating. The Bipartisan Infrastructure Law (BIL), CHIPS and Science Act (CHIPS), and, most importantly, the Inflation Reduction Act (IRA) have transformed the energy landscape, providing long-term policy certainty and unlocking billions in private-sector investment.

Together, these laws have triggered a clean manufacturing renaissance. Across the country, factories that make solar panels, wind turbines, and batteries are breaking ground or ramping up production. Construction spending on clean energy manufacturing has nearly tripled since 2020, and the number of new and expanded facilities has more than doubled since the IRA was signed in 2022 (Figure 2).

Figure 1: America's Historical and Future Energy Grid [6,7]

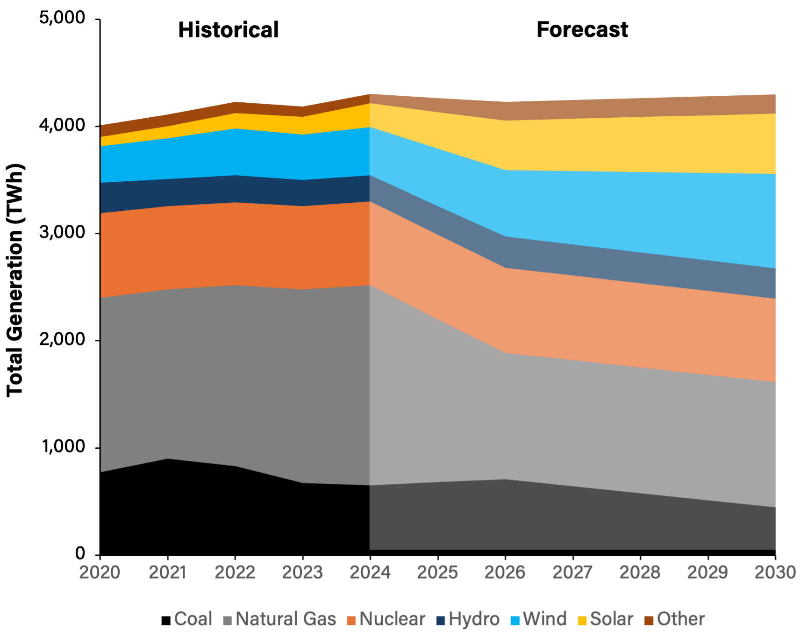
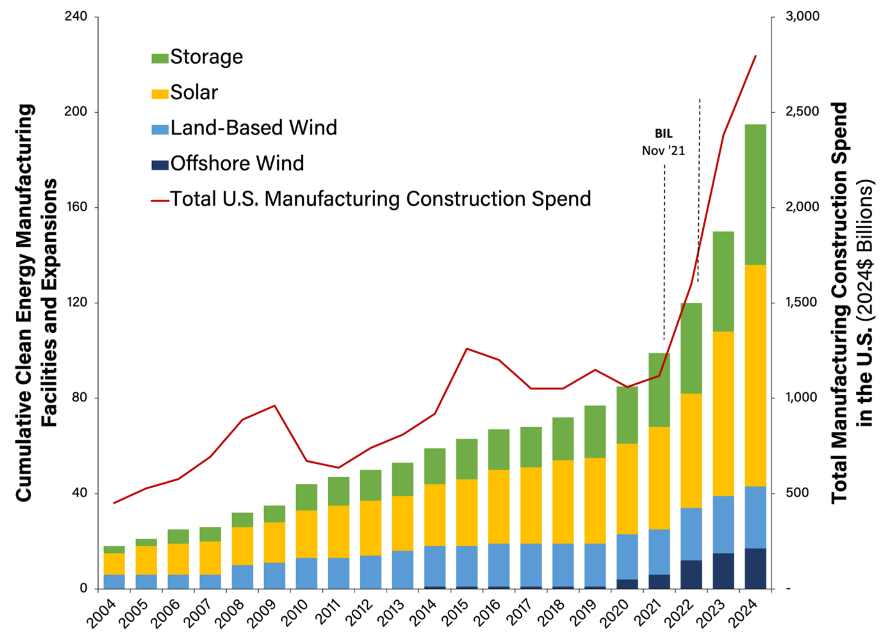


Figure 2: Annual Construction Spend and Clean Energy Manufacturing Grow in Tandem[8]



6 U.S. EIA. (March 2025). Monthly Energy Review. Retrieved from: https://www.eia.gov/totalenergy/data/monthly/

7 Future scenario based off NREL's "Standard Scenarios" (2024). NREL/TP-6A40-92256. Retrieved from: https://scenarioviewer.nrel.gov/?project=5573be35-16d1-4bc3-8c4d-38529c7bb640&mode=view&layout=Default

8 Source: U.S. Census Bureau Value of Construction Put in Place Survey

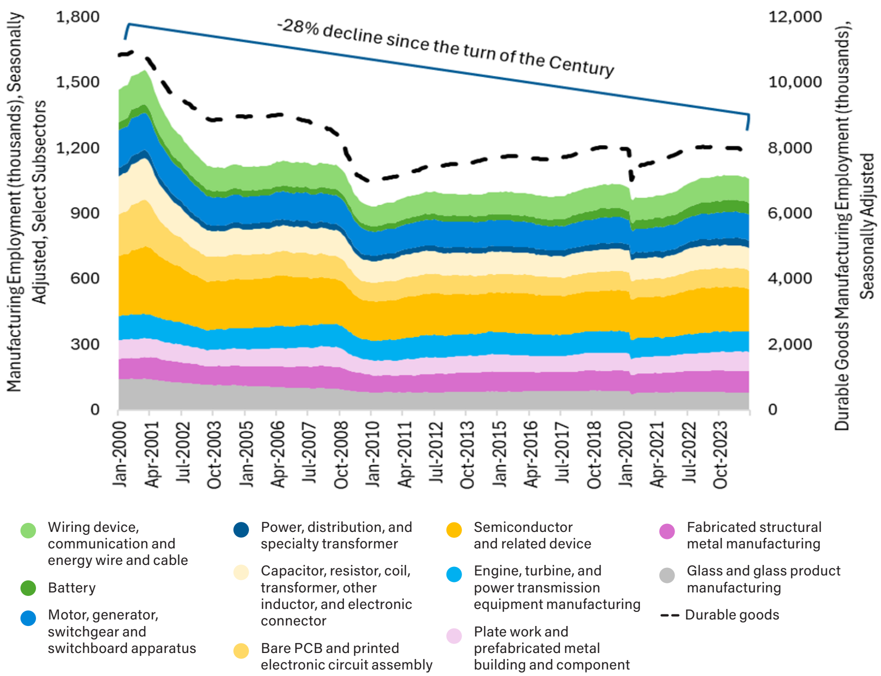
Why Now?

America's power needs are growing fast—projected to rise 35–50% by 2040—as data centers expand, domestic manufacturing rebounds, and our transportation and buildings electrify.[9] This demand presents a growth opportunity for the clean energy industry, but its not without challenges: outdated grid infrastructure persists, permitting processes are too lengthy, and global supply chains are fragile.

That is why building clean energy at home matters. A resilient, American-made supply chain for clean energy technologies makes the economy stronger, the country's energy more secure, and serves as the foundation for innovation and growth.

For too long, U.S. manufacturing declined—especially in energy-related sectors. From 2000 to 2024, energy manufacturing jobs dropped 28%, mirroring broader losses in durable goods production (Figure 3). The pandemic laid bare the risks of overreliance on overseas supply chains, with lead times for critical components like semiconductors stretching from months to over a year.[10]

Figure 3: Historic Employment Trends of Select Subsectors of Clean Energy Manufacturing, 2000-2024.[11]



Investments That Work

The IRA not only created demand for clean electricity—it gave manufacturers reasons to build in America. Key incentives include:

- **45Y/48E Clean Electricity Tax Credits:** Reward tech-neutral generation projects, especially those using U.S.-made components and paying prevailing wages.
- **45X Advanced Manufacturing Production Credit:** Directly supports domestic production of clean energy components across the supply chain.
- **48C Advanced Energy Project Credit:** Offers up to 30% of capital investment for manufacturing projects, with priority for those in former coal communities or with strong workforce development plans.

These programs are not just policy—they are reshaping the map. Public and private funding is giving new life to energy communities once anchored by now decommissioned fossil fuel projects by prioritizing prevailing wages, community benefits, and retraining initiatives, the IRA ensures this transition creates real opportunities for American workers.

The Bottom Line

The U.S. clean energy manufacturing industry is not just growing—it is being rebuilt from the ground up. With smart policies, rising demand, and a commitment to building resilient supply chains, the U.S. is poised to lead the world in clean energy innovation and production.

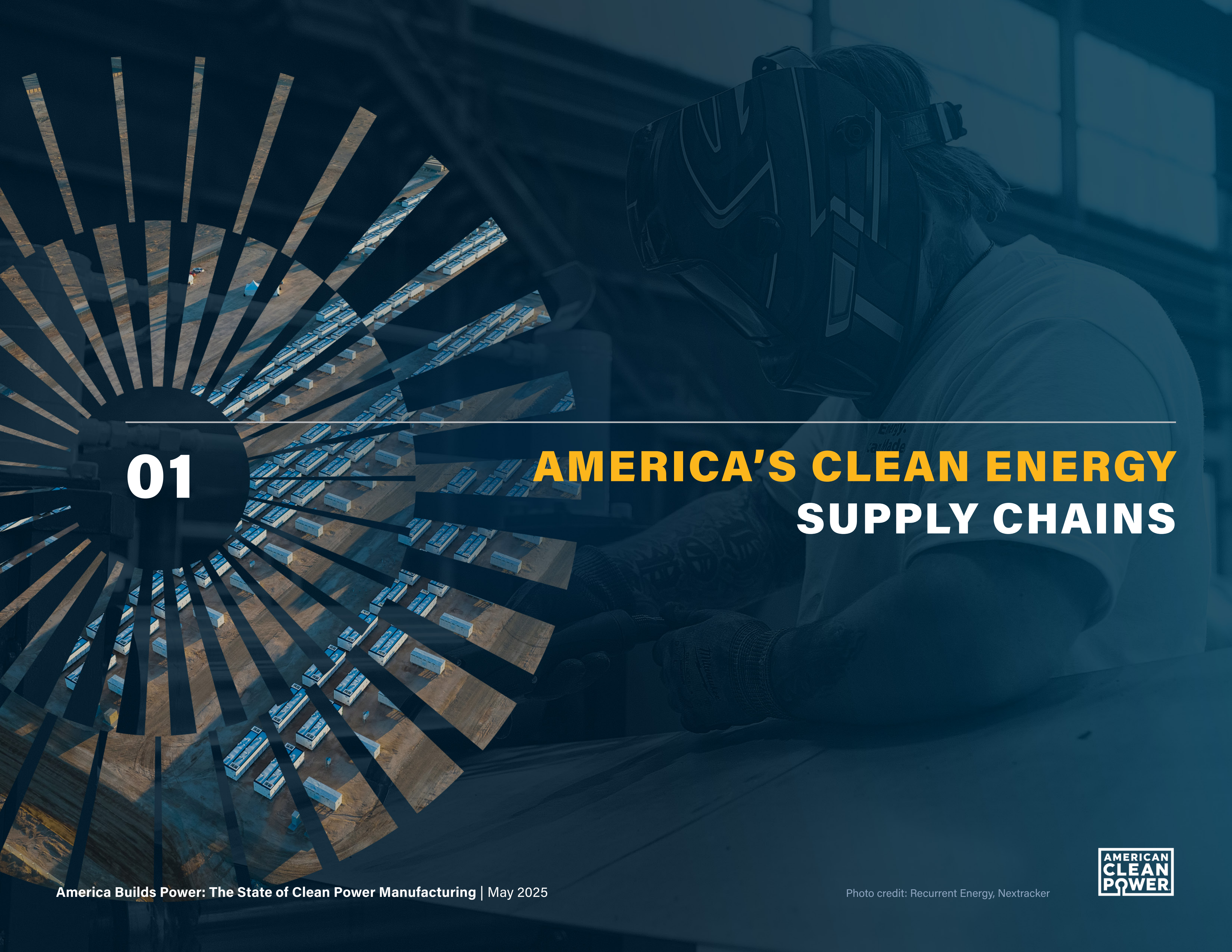
This is more than a climate milestone. It is a chance to revitalize American industry, create high-quality jobs, and power our future with energy that is made in America.

The following report will lay out how America's current clean energy manufacturing supply chain looks like today and near-term expectations. It will then turn to the direct economic impact our current facilities and expansions have seen and what we can expect based on under construction and announced facilities. Finally, it will highlight we can ensure continued success in the reshoring of manufacturing in the U.S.

9 S&P Global (March 2025). "U.S. National Power Demand Study." Retrieved from: https://cleanpower.org/wp-content/uploads/gateway/2025/03/US_National_Power_Demand_Study_2025_ExecSummary_FINAL-v2.pdf

10 S&P Global (July 2023). "S&P Global Mobility: The semiconductor shortage is—mostly—over for the auto industry." Retrieved from https://www.spglobal.com/mobility/en/research-analysis/the-semiconductor-shortage-is-mostly-over-for-the-auto-industry.html

11 Source: Bureau of Labor Statistics Current Employment Statistics. These are not employment levels in clean energy manufacturing, rather selected manufacturing subsector classifications that clean energy manufacturing jobs fall under. These subsectors also produce goods for other intermediate and end use sectors (e.g. automobiles and pharmaceuticals).



01 AMERICA'S CLEAN ENERGY SUPPLY CHAINS

Photo credit: Recurrent Energy, Nextracker

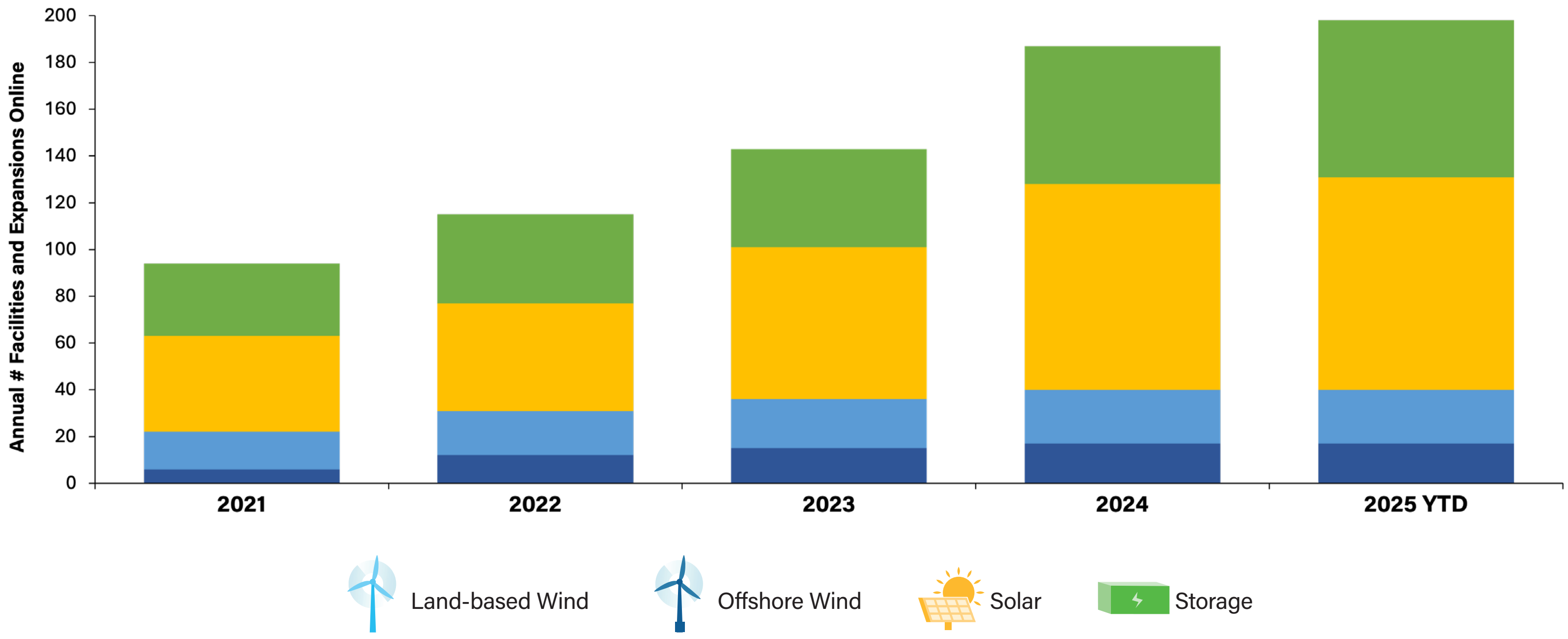
AMERICA'S CLEAN ENERGY SUPPLY CHAINS

The wind, solar, and battery storage industries rely on distinct, technology-specific supply chains, each with their own complex and globally interconnected network of components, subcomponents and raw materials that are processed, engineered and traded across multiple borders before reaching a project site. Strengthening domestic clean energy manufacturing supply chains represents an important opportunity for U.S. economic growth, energy security, and accelerated innovation.

The clean energy manufacturing sector in the U.S. is rapidly expanding, driven by rising energy demand, accelerating deployment of renewable technologies, and a suite of federal incentives aimed at bolstering domestic supply chains. As of early 2025, there are 200 primary manufacturing plants supporting the clean power industry, including 40 wind, 90 solar, and greater than 65 grid-scale energy storage manufacturing facilities. In 2024 alone, the industry added 45 new facilities—a 45% increase from the previous year—with growth spanning across all three technologies (Figure 4).

In total, over 250 new facilities have been announced since the passage of the IRA of which more than 95 are operational, over 45 are under construction, and 110 are in development. This surge includes nearly 20 wind-related, more than 110 solar-related, and close to 125 storage-related manufacturing facilities or expansions, underscoring the breadth of industry's expansion. And this doesn't even capture the hundreds of upstream facilities that supply the industry with subcomponents, parts, raw materials, and other inputs. This renaissance in clean energy manufacturing has positioned the U.S. for greater energy security, economic opportunity, and technological leadership.

Figure 4: Cumulative Online Utility-Scale Solar, Wind and Battery Energy Storage Systems Manufacturing Projects[12]



12 This representation only considers facilities that are currently still online and does not include mothballed or closed projects in the historical figures.

Solar

The U.S. is reentering the solar manufacturing market after decades of Chinese and Southeast Asian dominance. Initial entry began with module manufacturing, tracker and racking production. Domestic cell production production is becoming the next focal point, and while it is still nascent, dozens of facilities are seeking to supply the U.S. market. Ingot and wafer manufacturing is still largely in the exploratory stage and could provide a demand outlet for domestic polysilicon production.

Domestic Solar Manufacturing

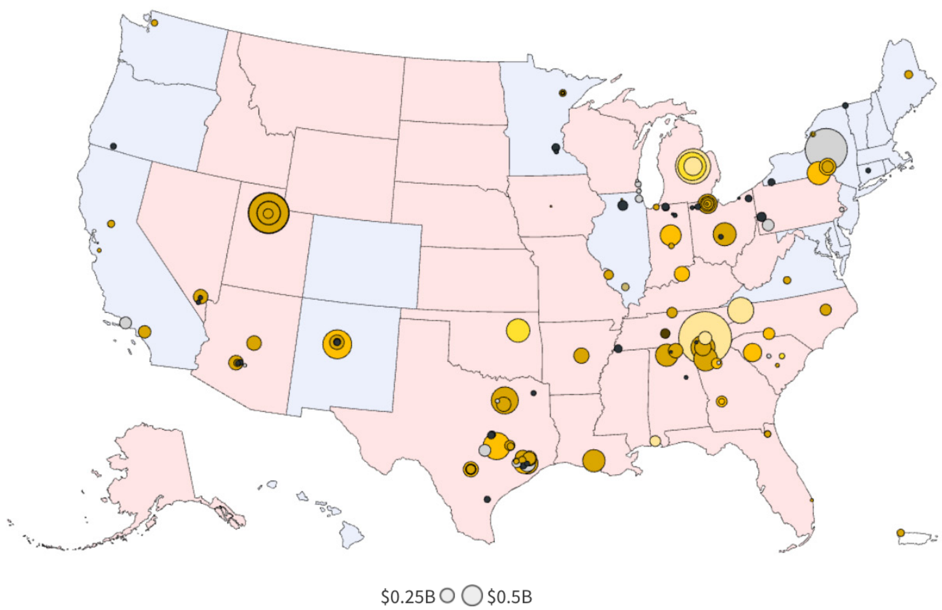
The IRA 45X tax credit has been the single-biggest driver of new U.S. solar manufacturing investments by providing domestic producers with direct incentives with 10 years of investment-grade certainty (Table 1). The industry has announced over 110 new utility-scale solar manufacturing facilities or expansions since August of 2022. 90 solar component manufacturing facilities are operating in the United States, with more than 15 additional manufacturing projects under construction and over 40 announced.

Solar manufacturing facilities are coming online across the country, with clusters forming in the Southeast, the Midwest, and Texas (Figure 5). The majority (75%) of solar manufacturing presence is in states that voted Republican in the 2024 election. States with the largest number of online component manufacturing facilities or expansions include: Texas (18), Ohio (11), and Alabama (6). Should all of the under construction and announced manufacturing projects successfully commission, the top states become Texas (26), Ohio (16), Georgia (9).

Table 1: Domestic Utility-Scale Solar Primary Component Manufacturing Incentives, Facilities and Expansions[13,14]

Primary Components	45X Credit Amount	Online	Under Construction	Announced
Module	7¢/W_{dc}	35	6	23
Trackers[15]	87¢/watt, $2.28/kg	25	1	-
Racking	-	7	-	1
Inverter	0.25¢/W_{ac} - 11¢/W_{ac}	13	1	1
Cell	4¢/W_{dc}	3	4	16
Ingot/Wafer	$12/square meter	1	2	3
Solar-Grade Polysilicon	$3/kg	4	-	2

Figure 5: Online, Under Construction, and Announced Domestic Utility-Scale Solar Component Manufacturing



13 ACP Data tracks capacity expansions and original capacity announcements individually, thus the number online, under construction and in development may exceed the number of physical manufacturing plants.

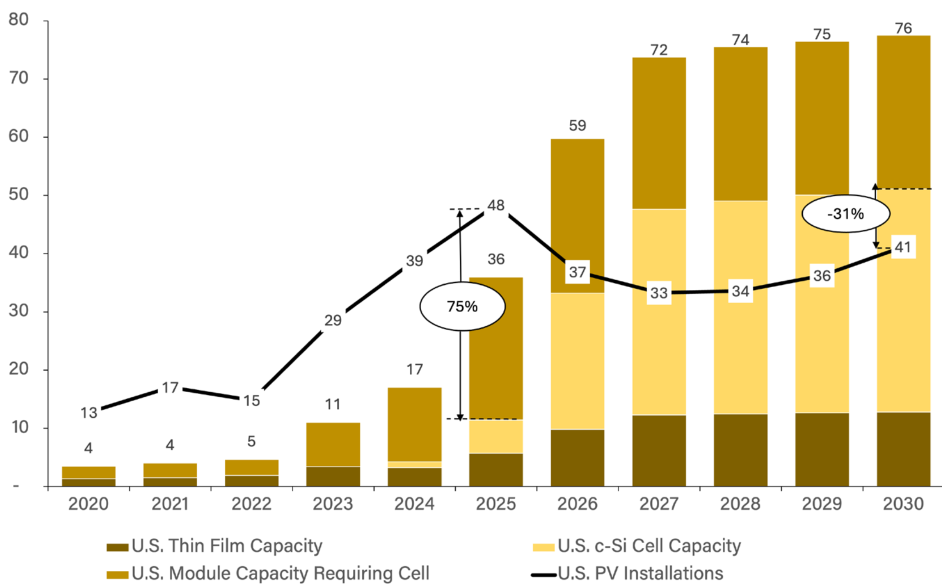
14 The numbers are indicative of CdTe and c-Si plants and expansions.

15 Torque tubes and structural fastener manufacturing is tracked under tracker manufacturing.

The growth in domestic solar manufacturing began with downstream solar module production as seen in Figure 6. That has since expanded into more upstream components of the value chain (cells, wafers and polysilicon) in earlier stages of development. Dozens of manufacturing facilities are now producing inverter and tracker components as well.

Today, the U.S. has more than 20 GW_{dc} of online module capacity and approximately 3 GW_{dc} of c-Si cell capacity to support utility-scale solar. This leaves a 25% module and 75% cell gap with demand. However, if all announced projects come online as planned, total utility-scale capacity could exceed 75 GW_{dc} (modules) and 40 GW_{dc} (cells)—sufficient to meet projected solar project demand. This includes both crystalline silicon (c-Si) and vertically integrated thin film cadmium telluride (CdTe) technologies.

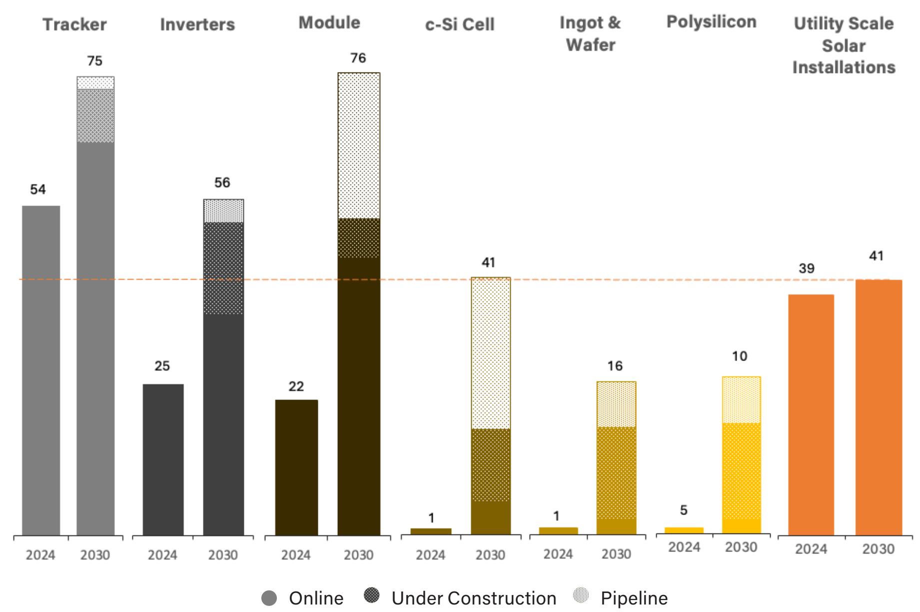
Figure 6: Domestic Utility-Scale Cell and Module Pipeline: Online vs. Announced [16, 17]



Announced capacity in most component segments exceeds demand from projected deployments (Figure 7). In 2024 alone, 14 new or expanded c-Si solar module facilities nearly doubled utility-scale capacity to over 30 GW_{dc} total. Only a single c-Si cell production facility commissioned in the same year, adding under 1 GW_{dc} of c-Si cell capacity.

Thin-film CdTe manufacturing supply chains differ greatly from their c-Si counterparts. CdTe modules are produced through a vertically integrated process with all steps completed at a single facility.[18] In contrast, c-Si manufacturing is typically done through stand-alone manufacturing facilities producing polysilicon, ingots and wafers, cells and finally modules separately. The difference in the manufacturing process between the two technologies results in distinct capital investment requirements, job needs, and timelines for bringing new facilities to market.

Figure 7: Domestic Utility-Scale Solar Manufacturing Supply Chain Online and Announced Capacity [19, 20]



16 Source: CPIQ, BNEF, Company Interviews, CEA

17 For capacity estimation methodology please refer to Manufacturing Methodology

18 U.S. Department of Energy (2023). Solar Photovoltaic Manufacturing Basics. Retrieved from: https://www.energy.gov/eere/solar/solar-photovoltaic-manufacturing-basics#:~:text=Thin%20film%20PV%20can%20refer,holes%20in%20the%20rear%20glass.

19 Source: CPIQ, BNEF, Company Interviews, CEA

20 For capacity estimation methodology please refer to Manufacturing Methodology

Moving Up the Value Chain: Wafers, Ingots, and Polysilicon

Supply chain resilience requires building upstream components that support domestic solar cell and module production. Today, the U.S. has no commercial-scale solar ingot and wafer manufacturing capacity, but that is rapidly changing. Currently, two companies (QCells and Corning) are building facilities that will add around 6 GW_{dc} of ingot and wafer production capacity to support utility-scale solar demand. If all announced and under-construction projects are completed, the U.S. could exceed 15 GW_{dc} of ingot and wafer capacity for utility-scale solar by 2030.[21]

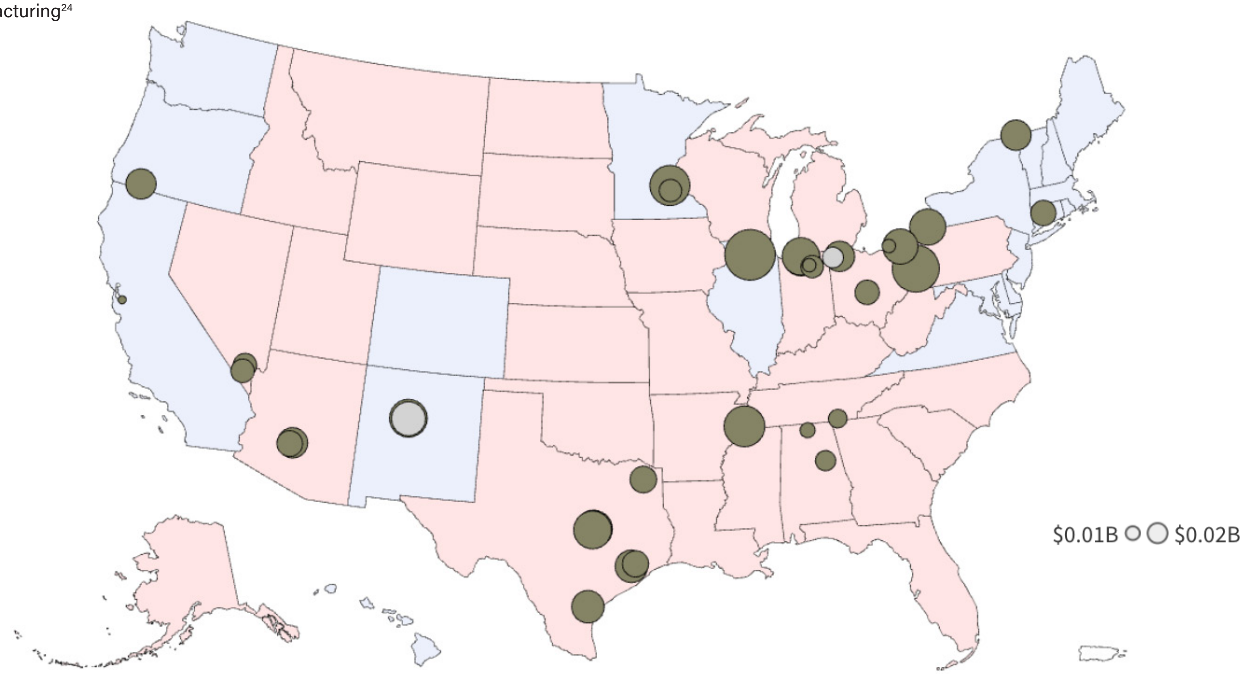
1. Solar polysilicon production has the longest history of any component in the solar supply chain. For example, Hemlock's Michigan facility started production of purified silicon in 1960 and has been a major global supplier of solar polysilicon for decades. Market growth and a growing domestic supply chain have buoyed domestic polysilicon suppliers' cost competitiveness. In 2024, U.S. producers directed 4.5 GW_{dc}-equivalent of polysilicon to the solar industry, with expectations to reach nearly 10 GW_{dc} by 2030. [22,23]

Projects like Highland Materials' new facility in Tennessee, supported by a $255 million federal grant, represent the kind of upstream investment needed to anchor the rest of the value chain. [25] However, these projects often face uncertain demand because they depend on the timely commissioning of ingot and wafer facilities. Expanded wafer production is therefore a key market signal to unlock further polysilicon capacity.

Solar tracker and racking manufacturing have been another area of domestic growth. Production incentives for torque tubes and fasteners coupled with domestic steel inputs has led to a proliferation of dedicated lines at steel mills for these solar components.

There are over 30 manufacturing locations in 17 states that currently produce parts to support domestic trackers and racking as highlighted above in Figure 8. With an additional four tracker or racking manufacturing facilities announced, solar tracker and racking production is well positioned to satisfy future demand.

Figure 8: Domestic Tracker and Racking Manufacturing[24]



21 ACP assumes available ingot/wafer capacity for utility-scale solar is proportional to the market share split with residential solar.

22 Source: Company Interviews, CEA

23 Polysilicon capacity available to satisfy utility-scale solar demand is reduced to consider demand pulls from residential solar and the semiconductor supply chain.

24 Polar Racking announced planned manufacturing capacity in Michigan and Florida. Site specifics have not been announced publicly.

25 U.S. Department of Energy (2024). Applicant Self-Disclosed 48C Projects. Retrieved from: https://www.energy.gov/mesc/applicant-self-disclosed-48c-projects

Domestic Solar Manufacturing in Action: Nextracker

At the intersection of surging solar demand and America's steelmaking legacy, Nextracker is reshaping domestic tracker manufacturing. The company has forged partnerships with dozens of suppliers across Indiana, Illinois, Arizona, Texas, Tennessee, Alabama, Kentucky, North Carolina, Mississippi, and Wisconsin, among others—building a robust, coast-to-coast manufacturing network for critical tracker components (Table 2). From low-carbon steel torque tubes to advanced slew drives and smart electronics, Nextracker is helping define a new era of American solar manufacturing.

Table 2: Nextracker steel partnerships for solar tracking components [26]

Location	Partner Company	Facility Component	Capacity (GW_{dc})	Investment ($Million)	Full Time Jobs
Phoenix, AZ	Atkore	Steel tracker components	*	*	*
Fremont, CA	Asteelflash	Self-powered controllers	12.5	>$1	30
Leetsdale, PA	JM Steel	Solar tracker components	4.0	>$100	60
Memphis, TN	MMS Steel Tubes	Steel torque tubes	4.5	$7	103
Las Vegas & Sloan, NV	Unimacts	Steel torque tubes	2.0	*	>100
Sinton, TX	JM Steel	Solar tracker components	6.0	>$45	>30

As of 2024, Nextracker has invested almost $315 million in U.S. manufacturing in seven American cities, adding over 50 GW_{dc} of solar tracker component manufacturing. These line additions generated over 2,000 construction jobs during the construction phase of the projects. The company's investments have created almost 1,200 direct and permanent manufacturing jobs with room for growth. Nextracker's U.S. workforce enjoys access to well-paying careers, ongoing skills training, and long-term advancement opportunities. These investments are not just about building solar hardware—they are building futures and powering American communities.

As America seeks to reclaim leadership in clean energy manufacturing, Nextracker offers a powerful model—one rooted in industrial know-how, local investment, and unwavering commitment to sustainability. The company's expanding footprint demonstrates how domestic manufacturing can fuel the clean energy transition while strengthening economic resilience in cities both old and new.

Figure 9: Torque Tube Manufacturing at a Unimacts & Nextracker Manufacturing Line [27]

26 Some company partnership details have not been released publicly. These details are denoted with an asterisk ("*").

27 Photo courtesy of Nextracker.

Domestic Solar Manufacturing in Action: First Solar

Making strides to increase solar panels with domestic content; First Solar has invested over $4 billion across the country in onshoring thin film manufacturing.

The company started the early 2000s with 6 MW_{dc} of manufacturing in Ohio and today operates three plants with a cumulative annual nameplate capacity of 7 GW_{dc} at its campus in Wood County, Ohio. In addition to the $1.9 billion in direct capital investment injected into its Ohio factories, First Solar has also spent approximately $0.5 billion on R&D infrastructure as it expanded its footprint in the state. Today, First Solar directly employs over 2,400 people in Ohio, including manufacturing workers, R&D staff, and support services. It estimates that it supports over 10,500 direct, indirect, and induced jobs in the state, representing labor income of approximately $1 billion.

First Solar has capitalized on a first-mover's advantage in the American market through its scale and speed-to-market. On the heels of opening the Ohio locations, First Solar has also successfully commissioned a fully vertically integrated thin film manufacturing plant in Trinity, Alabama. This $1.1 billion investment added an additional 3.5 GW_{dc} to the domestic solar supply chain. Construction alone employed 1,800 workers and now supports 800 full-time manufacturing jobs with an average salary of $80,000 per year.

Further expanding its capacity, First Solar recently completed construction of a 3.5 GW_{dc} plant in Iberia Parish, Louisiana, which it expects to commission in the second half of 2025. Once fully operational, this $1.1 billion investment will employ over 800 full-time workers. First Solar's Louisiana facility provided almost 1,500 construction jobs during this construction period.

In 2026, First Solar expects to support over 30,000 direct, indirect, and induced jobs across the country, representing almost $2.8 billion in labor income. They forecast it will add nearly $5 billion in value to the US economy and account for over $10 billion in economic output.

First Solar is actively engaged with the local communities in Ohio, Alabama and Louisiana to support the growing workforce needs. From partnering with local workforce development groups to funnel local talent into these new well-paid roles, to collaborating with community colleges to build robust training programs, the company has dedicated considerable time and funding to the benefits it provides.

Figure 10: Manufacturing at First Solar's Perrysburg, Ohio Thin Film Plant[28]

28 Photo: REUTERS/ Megan Jelinger. 2022. Available from: https://www.cnbc.com/2024/03/05/first-solar-ceo-says-tariff-exemptions-threaten-us-efforts-to-ramp-up-manufacturing.html

Solar Component Trade Flows

As utility-scale module manufacturing for products in the U.S. has started to come online, imports have slowed and, in 2024, decreased for both thin-film and c-Si modules. In 2024, the solar industry imported $14.8 billion of solar modules, including over $11.5 billion of c-Si modules and just over $3.0 billion of thin-film modules (Figure 11). This represents an almost 30% decrease in module imports compared to 2023, despite the industry installing a record amount of solar power capacity in 2024.

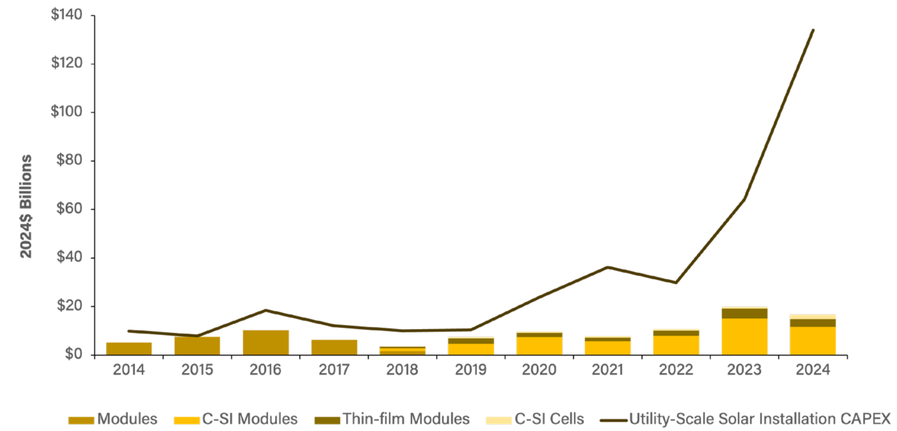
Currently domestic nameplate utility-scale module production capacity totals over 20 GW_{dc} annually. This is a marked increase in capabilities of just a few years ago but is still short of being able to meet domestic demand. Utility-scale solar installations reached a record-breaking capacity of over 30 GW_{dc} in 2024, a 55% increase compared to 2023, and are expected to grow, leaving the industry dependent on module imports for a portion of supply. Developers have strong business incentives to use domestic products including their lack of tariff exposure and cheaper logistics expenses to get products on-site.

Solar cell import trends reinforce evidence of a budding domestic module manufacturing industry. A record $1.8 billion of solar cells were imported in 2024. This is more than double the $748 million imported in 2023. As the industry seeks to build domestic solar cell manufacturing capacity, solar module manufacturers must rely on imported cells. New domestic cell production is in its very early stages of growth, but the trend line is promising. As these new domestic cell production lines come online, domestic module manufacturers can increasingly source domestic cells which benefit from the same business incentives as modules regarding lack of tariff exposure and lower logistics costs.

This market activity is confirmation of the natural migration of supply chains. First the end-use manufacturing facilities are built. They attract their supply chain partners to relocate and those manufacturers, in turn, incentivize their component suppliers to set up shop in the U.S. As solar cell manufacturing is established, the next logical step is for ingot and wafer imports to be established until they can fully supply the domestic market.

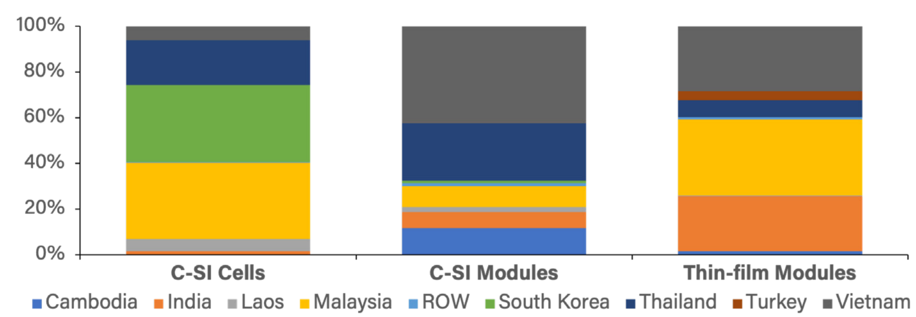
The U.S. primarily imports solar modules from Southeast Asia, India, and South Korea. Thin-film modules are predominantly sourced from Malaysia (33%), Vietnam (28%), and India (24%), while c-Si modules come from Vietnam (40%), Thailand (24%), Cambodia (11%) and Malaysia (9%). C-Si module imports trended down from 2023's peak of $15.1 billion, to $11.7 billion in 2024. Thin-film module imports followed a similar trajectory, down to $3.1 billion in 2024 from $4 billion in 2023. Module imports are expected to continue to decline as a share of solar project installations, but they will still be necessary to meet growing demand.

Figure 11: Solar Cell and Module Imports by Year[29]



The top solar cell providing countries are South Korea (33%), Malaysia (32%), and Thailand (19%). Cell imports increased exponentially to $1.9 billion in 2024. Korean cell imports continue to grow, more than triple from last year's record high. Cell imports from Thailand grew 85 times. As previously anticipated, the commissioning of another 14 solar module manufacturing facilities has driven cell demand to new heights. As with module imports, solar cell import reliance will subside once more announced and under construction projects commission. The dependence on ingot and wafer imports has the potential to wane, though the mismatch between domestic cell demand and wafer production indicates that imports of ingots and wafers will be a necessity for the coming years.

Figure 12: 2024 Top Import Country by Component Harmonized Tariff Schedule Code[29]



29 USITC Dataweb.2025.Available from: https://dataweb.usitc.gov/

The Trump Administration has consistently shown that an aggressive tariff policy is a key aspect of its overall economic agenda. This focus is particularly impactful for the sectors that have import dependence. In addition, the Administration has coupled its frequent use of tariffs with a stated goal of reducing "trade in goods" deficits with countries who sell the U.S. more manufactured goods and commodities then the U.S. buys. Five of the top 15 countries (by 2024 U.S. trade deficit) are also current top solar exporters to the U.S. Base tariffs, antidumping and countervailing duties (AD/CVD), Section 201, Section 301, Section 232 and the most recent International Emergency Economic Powers Act (IEEPA) tariffs impact these countries, and companies within these countries, differently.

As it stands, solar cells from South Korea, Malaysia, Vietnam, Thailand and Laos all have baseline most-favored-nation (MFN) tariffs of 0%, but additional tariffs stack on top of this baseline 0% tariff is then stacked with the 14% Section 201 tariffs once the 12.5 GW_{dc} annual tariff-rate quota is satisfied, and the additional IEEPA tariffs if reinstated (Table 3).[30] AD/CVD rates increase these percentages further by country and company. Country wide dumping rates for Malaysian imports are 8.59%, 111.45% for Thailand, and 271.28% for Vietnam based on the company exporting the cells to the U.S. Countervailing duty rates for Malaysian imports are 32.49%, 263.74% for Thailand, and 124.57%.[31]

Only low volumes of solar ingot and wafer have been imported as domestic solar cell manufacturing is nascent. Wafer imports from China are subject to Section 301 tariffs of 50%, stacked with the recent China IEEPA tariffs (30%). As a result, early domestic cell manufacturers are primarily using wafers sourced from Japan, Taiwan, and Southeast Asia. Polysilicon is also subject to Section 301 tariffs (50%) for Chinese imports along with the IEEPA tariffs noted above. Prospective domestic ingot and wafer producers have commercial contracts with domestic and Malaysian sources of solar polysilicon.

Solar racking and tracker components are expected to absorb the latest Section 232 tariff of 25% on steel and aluminum in addition to IEEPA tariffs and any additional baseline MFN tariffs, all based on origin of the product. Given the traction and announcements in the solar tracker and racking space, by partnering with American steel mills, domestic manufacturing appears well positioned to manage the elevated import costs.

Other materials in the solar supply chain, such as solar-grade glass and aluminum components have fewer readily available domestic sourcing options. First Solar has partnered with glass suppliers like Vitro in Pennsylvania for domestic thin film solar glass and U.S. manufacturers like SOLARCYCLE are beginning to invest in domestic c-Si glass capacity.[32] However, even with growing U.S. capacity, demand is expected to outpace domestic supply in the near term. In the meantime, many domestic module manufacturers will import solar glass from regions like Southeast Asia that are impacted by the IEEPA tariffs.

Table 3: 2025 Tariff Totals Across the Solar Supply Chain by Top Import Countries [33, 34, 35]

Component	2024 Top Import Country (by HTS Code)	Base tariff	Section 201	Section 232	Section 301	IEEPA	Total
Wafers	Japan	0%				24%	24%
	Taiwan	0%				32%	32%
	South Korea	0%				25%	25%
	Vietnam	0%				46%	46%
	China	0%			50%	30%	80%
C-Si Cells	South Korea	0%	14%			32%	46%
	Malaysia	0%	14%			24%	38%
	Thailand	0%	14%			36%	50%
	Vietnam	0%	14%			46%	60%
	Laos	0%	14%			48%	62%
Glass	Japan	5%				24%	29%
	China	5%			25%	30%	60%
	Netherlands	5%				20%	25%
	Italy	5%				20%	25%
	Egypt	5%				10%	15%
Solar Trackers (Aluminum & Steel)	Mexico	2.5%		25%		25%	52.5%
	Germany	0%		25%			25%
	Canada	2.5%		25%		25%	52.5%
	Vietnam	0%		25%			25%
	Taiwan	0%		25%			25%

30 All tariff information is rapidly evolving as trade negotiations are underway. All information is effective as of May 12, 2025 and subject to change as of publication.

31 AD/CVD tariffs applied represent country-wide tariffs or "All others" rates. Company-specific tariffs vary by company and country and are subject to annual review and adjustment.

32 SOLARCYCLE (February 15,2024). "SOLARCYCLE® to Open First-of-its-Kind Solar Panel Glass Plant in Georgia." Retrieved from: https://www.solarcycle.us/press-releases/solarcycle-to-open-first-of-its-kind-solar-panel-glass-plant-in-georgia

33 Section 201 imposes a 14% tariff on all module and cell imports from February 7, 2025 to February 6, 2026. For cells, imports of up to 12.5 GW_{dc} annually are exempt from the tariff. Over-quota cell imports are subject to the 14% tariff rate. Exempt countries include Canada, Cambodia, Jordan, and Indonesia. The 201 tariff impacts all modules (both bifacial and monofacial) and cells.

34 Imports from Mexico and Canada are not subject to the 25% IEEPA fentanyl tariff if the imported production is USMCA-compliant, however the rate of 25% is assumed for illustrative purposes assuming non-compliance.

35 For IEEPA tariffs, while the announced reciprocal tariff rates are currently paused until July 8, 2025 pending negotiation with the Administration, the announced rates are used in this analysis for illustrative purposes.

Wind

Land-based wind component manufacturing is well-established, with U.S.-based factories building primary components (blades, towers, and nacelles) as well as secondary parts like bearings, slip rings, brake systems, fasteners, power converters, and sensors. Land-based wind component manufacturing has grown such that over 80% of nacelle assembly and close to 70% of tower manufacturing takes place domestically.[36] There are now close to 400 primary and secondary component facilities supporting the land-based and offshore wind industries.

Domestic Land-Based Wind Manufacturing

The initial rise of American wind component manufacturing was driven by strong market demand coupled with clear economic and logistical advantages. The sheer size of wind components makes international shipping expensive, giving U.S.-made parts a cost edge. At the same time, the just-in-time delivery requirements of wind projects—where storing massive blades, towers, and nacelles is impractical—meant proximity to project sites was critical. These factors, combined with steady technological progress and policy support, allowed wind manufacturing to establish a foothold in the U.S.

There are 390 domestic, land-based wind manufacturing facilities or expansions projects spread across 43 states that produce many of the more than 8,000 parts and components that make up a modern wind turbine. At the heart of this supply chain are over 20 primary component (nacelle, tower, blade or cables) manufacturing plants.[37] These plants - many of which have been in operation for more than a decade - have increasingly sourced from U.S.-based manufacturers and spurred their suppliers to establish domestic manufacturing capabilities.

Three of the four major wind turbine original equipment manufacturers (OEMs)—GE Vernova, Nordex, Siemens Energy, and Vestas—have at least one nacelle facility or are re-opening a nacelle manufacturing facility in the U.S. Total nacelle manufacturing represents well over $200 million in capital investment. Alongside these plants are 12 tower manufacturing sites or expansions, including four owned by Arcosa. Siemens Gamesa, Vestas, and GE Vernova each own a blade manufacturing facilities in the U.S.

The domestic wind supply chain has been reinvigorated in the past couple years. Since 2022, the land-based wind industry has opened or expanded 6 manufacturing plants, has started construction at one, and has announced plans to reopen 3 facilities.

Table 4: Domestic Land-Based Wind Primary Component Manufacturing Incentives, Facilities and Expansions[37]

Primary components	45X Credit Amount	Online	Under Construction	In Development
Blades	2¢/W	3	1	-
Nacelle	5¢/W	4	2	-
Tower	3¢/W	12	-	-
Cables	*	3	-	-

36 U.S. Department of Energy (2022). "Wind Manufacturing and Supply Chain." Retrieved from: https://www.energy.gov/eere/wind/wind-manufacturing-and-supply-chain

37 ACP Data tracks capacity expansions and original capacity announcements individually, thus the number online, under construction and in development may exceed the number of physical manufacturing plants.

*While 45X does not extend a production tax credit for cable manufacturing, 48C does extend investment tax credits to cable manufacturing.

Combining reopening plans with existing facilities, the total number of land-based wind primary component facilities is expected to rise to nearly 30 (Figure 13). Beyond the additional 3 tower, 4 nacelle, 2 blade and cable manufacturing facilities or expansions, the demand stimulus since August 2022 has resulted in complementary secondary manufacturing projects along the supply chain such as nacelle cover manufacturing and component recycling facilities.

Domestic blade production has been more volatile than turbine and nacelle production. Production capacity, while expanding, still trails demand. By 2026, new investment in blade production is expected to add ~1.4 GW of capacity, bringing total domestic blade capacity to over 5.5 GW.

Federal incentives and long-term demand have proven effective in stimulating land-based wind manufacturing expansion. Nacelle manufacturing capacity is currently greater than 14 GW and could grow by more than 50% over 2024 levels by 2030 if all announced facilities come online and reach full operation. Tower manufacturing capacity is over 12 GW as of 2024 and has grown steadily since 2022, increasing by roughly 1.3 GW per year. Both nacelle and tower production capacity trend closely with national demand.

Figure 13: Primary Land-Based Wind Component Manufacturing Locations Online and Pipeline

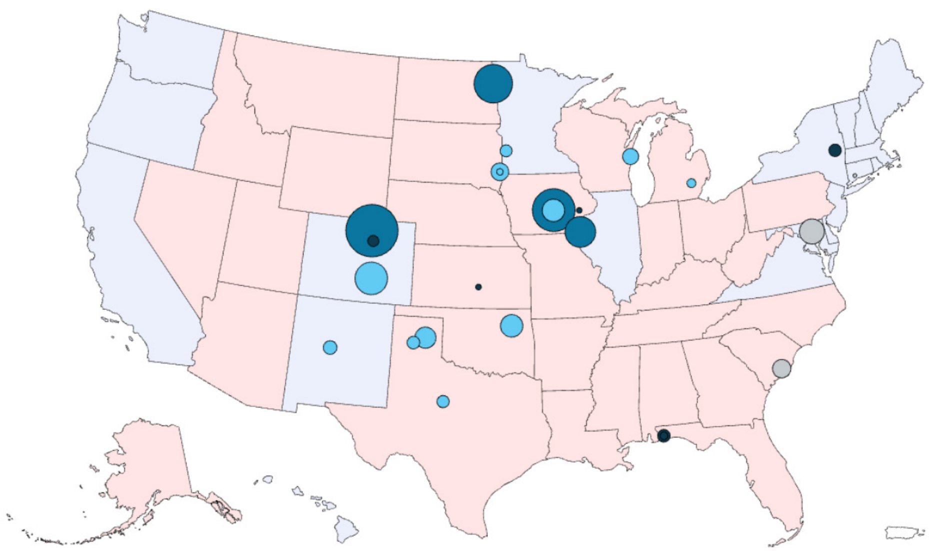
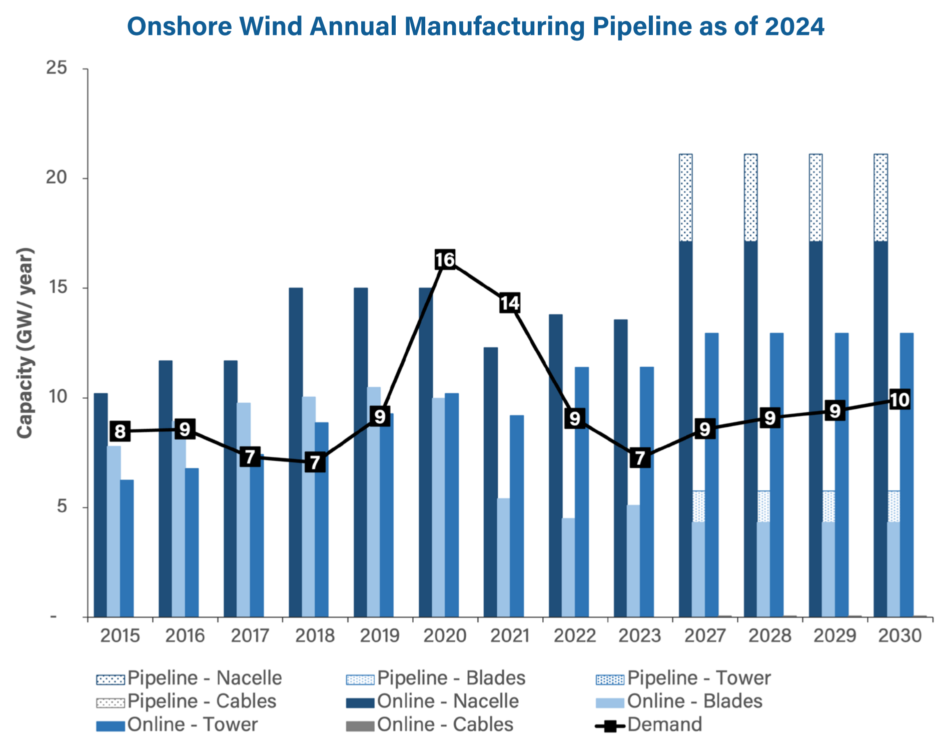


Figure 14: Domestic Land-Based Wind Manufacturing Capacity[38,39]



38 Source: CPIQ, BNEF, Company Interviews, CEA, S&P Global

39 For capacity estimation methodology please refer to Manufacturing Methodology

Land-Based Wind Manufacturing in Action

With the restart of nacelle manufacturing at its West Branch, Iowa facility in 2025, Nordex is reinvigorating wind manufacturing in Iowa. Incentives from the IRA have provided demand tailwinds necessary to bring back the manufacturing of this vital land-based wind component. Nordex's Iowa facility will reshore 2.5 GW of annual nacelle manufacturing capacity beginning mid-year 2025. By shifting jobs and investment to the US from overseas, Nordex will boost domestic content for its land-based wind turbines.

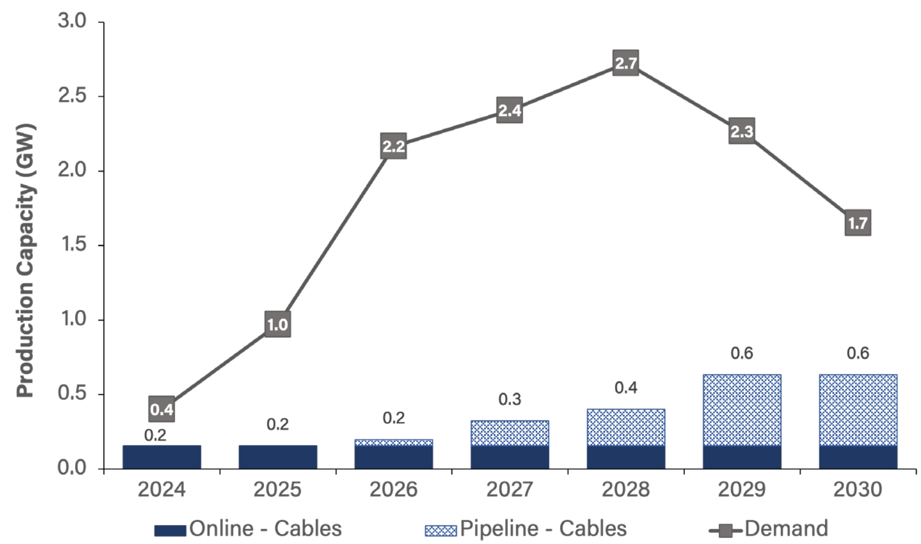
Figure 15: Nacelle Manufacturing in West Branch, Iowa[40]

Nordex has invested over $10 million in the updates required for recommissioning. Over 20 construction jobs stemmed from the work to bring the plant back online. Once fully operational, the West Branch facility will employ 120 full-time staff. Nordex is dedicated to recruiting within the local community to extend benefits directly to the community in which they operate. To cultivate a best-in-class manufacturing environment, the company offers its employees training programs, continued education opportunities as well as career development within the organization.

Domestic Offshore Wind Manufacturing

The offshore wind industry has begun investing in domestic manufacturing with cables and vessels. With strong financial and market driven support, offshore wind cable manufacturers have selected South Carolina, Virginia, and Maryland for capacity expansion. In 2024, Nexans, a domestic cable manufacturer, successfully installed cable for the 704 MW Revolution Wind Farm.[41] In the same year, Hellenic Cables and LS Cable were awarded funding through IRA's 48C investment tax credit to set up facilities in Maryland and Virginia, respectively, promising to create over 500 direct manufacturing jobs combined.[42] The Nexans facility in South Carolina supports 240 direct manufacturing jobs. The IRA has ignited domestic offshore wind cable manufacturing in the United States and demand proves there is opportunity for growth (Figure 16).

Figure 16: Domestic Offshore Wind Cable Manufacturing Capacity[43, 44]



40 Olivia Cohen. (August 17, 2024). "Wind turbine production to restart in West Branch." The Gazette. Retrieved from: https://www.thegazette.com/environment-nature/wind-turbine-production-to-restart-in-west-branch/

41 Nexans (March 10, 2022). "Nexans to supply Ørsted – Eversource offshore wind project serving Connecticut and Rhode Island states." Retrieved from: https://www.nexans.com/press-releases/nexans-to-supply-orsted-eversource-offshore-wind-project-serving-connecticut-and-rhode-island-states/

42 U.S. Department of Energy(2024). Applicant Self-Disclosed 48C Projects. Retrieved from: https://www.energy.gov/mesc/applicant-self-disclosed-48c-projects

43 Source: CPIQ, BNEF, Company Interviews, CEA

44 For capacity estimation methodology please refer to Manufacturing Methodology

Vessel manufacturing is another supply chain segment which has seen incredible domestic manufacturing growth but faces the same uncertain outlook. In response to the demand from planned offshore wind projects, and enhanced by the 45X tax credit, 21 offshore wind vessels have been built at American shipyards. Another 11 are under construction and 13 more are set to begin construction at American shipyards, up from just four vessels prior to 2022. There are 16 shipyards across the U.S. that have supported the construction of the 32 vessels that have been and that are currently being built (Table 5). One new shipyard is under development to begin vessel construction.

Table 5. Domestic Offshore Primary Component Manufacturing Incentives, Facilities and Expansions [45]

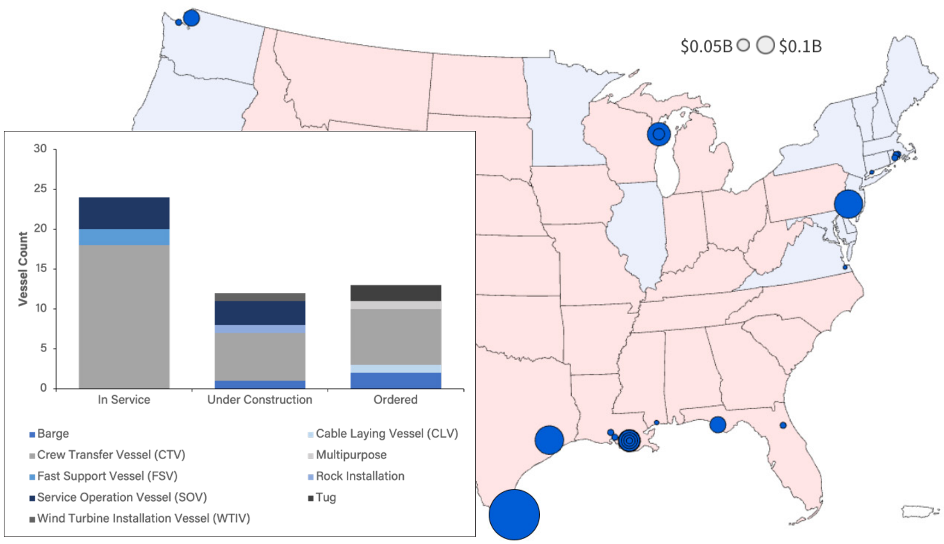
Primary components	45X Credit Amount	Online	Under Construction	In Development
Shipyards [46]	10% of vessel sale price for the shipyard	16	-	1
Cables	*	1	1	1

Nearly 50 vessels have been ordered or are in-service for the offshore wind industry amounting to over $2.4 billion in investments. In 2024, 12 of these domestically built or retrofit offshore wind vessels were launched and there remains $427 million in investments to be realized. This investment has resulted in job growth in shipbuilding. Oceantic Network cites 2,500 manufacturing jobs supported by just five of the thirteen domestic shipyards identified to be supporting the offshore wind industry.[47] Based on this estimate, thousands of additional vessel manufacturing jobs will be supported by offshore wind shipbuilding to satisfy the 13 vessels on order (Figure 17). Beyond the direct jobs stimulated by offshore wind shipbuilding, there are thousands of indirect jobs from the aluminum and steel manufactured within the U.S.

The opportunity for offshore wind manufacturing in the U.S. is significant. Large components like castings, forgings, and towers are mostly produced overseas because steel producers require more demand certainty to justify the major capital investment to retool or build new facilities. Policies like the IRA started to attract new U.S. investment by creating more predictable demand, but recent regulatory barriers have pushed the market back into extreme uncertainty.

The recent federal permitting and leasing halt for offshore wind projects caused several offshore wind manufacturers to cancel planned investments in early 2025. For example, Prysmian cited market uncertainty for terminating its plans for a cable manufacturing facility in Somerset, Massachusetts.[48] This cancellation alone dashed the opportunity for over 300 U.S. manufacturing jobs and more than $10 million in annual tax revenue for the local community. With global offshore wind energy demand on the rise, changing tides in the U.S. pose a threat to domestic onshoring in favor of regions with more stable political climates. Market clarity and the regulatory advancement of offshore wind projects would make domestic manufacturing of offshore wind components—particularly steel and iron products—more economically viable.

Figure 17: Domestic Offshore Wind Shipbuilding [49, 50]



45 ACP tracks capacity expansions and original capacity announcements individually, thus the number online, under construction and in development may exceed the number of physical manufacturing plants.

46 This is indicative of U.S. shipyards that have been or will be contracted for the purpose of a vessel used for offshore wind projects.

47 Oceantic (June 26, 2024). "A Shipyard Renaissance: Offshore Wind's Economic Impact on American Maritime." Retrieved From: https://oceantic.org/a-shipyard-renaissance-offshore-winds-economic-impact-on-american-maritime/

48 Ben Berke (January 22, 2025). "Prysmian abandons plans for offshore wind cable factory in Somerset." The Public's Radio. Retrieved from: https://thepublicsradio.org/business/prysmian-abandons-plans-for-offshore-wind-cable-factory-in-somerset/

49 Source: CPIQ, Company interviews, Spinergie

50 Note that not all ordered vessels have announced shipyards and are thus not on the map.

Offshore Wind Manufacturing in Action

Strategically positioned along the East Coast's Chesapeake Bay, LS Cable & System will begin construction of a high voltage direct current (HDVC) subsea cable manufacturing and pier facility supporting offshore wind generation and interconnection projects. LS GreenLink, the U.S. subsidiary of LS Cable & System, will bring more than $681 million in capital investment to the City of Chesapeake. Not only does this investment apply to the manufacturing plant that has recently broken ground, but it also extends to added port infrastructure necessary to service offshore wind. Governor Glenn Youngkin of Virginia has expressed his support for the offshore wind plant through his approval of a $13.2 million grant and proclaiming that "LS GreenLink's investment in Virginia will showcase the Commonwealth as a leader in offshore wind industry manufacturing." [51]

An example of public sector funding amplifying private sector investment, this Virginia facility has been further supported by federal incentives. Selected to receive over $99 million from the 48C IRA tax credit, U.S. Senator Mark Warner applauds the IRA in saying, "thanks to this once-in-a-generation legislation, the clean energy industry is growing, and Virginia is benefiting."[52] To receive these federal funds, the project is required to meet prevailing wages and engage actively with the community. LS GreenLink has already begun to make good on those promises.

The subsea cable manufacturing facility will generate more than 330 direct manufacturing jobs and hundreds more construction and transportation- related employment opportunities. LS GreenLink highlights that the company is actively engaging with local communities, including schools, veterans' groups and trade associations, to create ways to offer employment to local communities. This subsea cable plant is a microcosm of the national potential of offshore wind to bring thousands of new manufacturing jobs to life. Developing talented workforces across the country, an undercurrent of the IRA, to support clean energy manufacturing is critical to ensuring energy security.

Figure 18: LS GreenLink Future Virginia Manufacturing and Pier Facility [53]

51 Adrijana Buljan (July 10, 2024). "LS Cable & System to Build 'Largest US Subsea Cable Factory' in Virginia." OffshoreWIND.biz. Retrieved from: https://www.offshorewind.biz/2024/07/10/ls-cable-system-to-build-largest-us-subsea-cable-factory-in-virginia/

52 Office of the Governor of Virginia (July 9, 2024). "Submarine Cable Manufacturer to Locate in Virginia." Retrieved from: https://www.governor.virginia.gov/newsroom/news-releases/2024/july/name-1030531-en.html

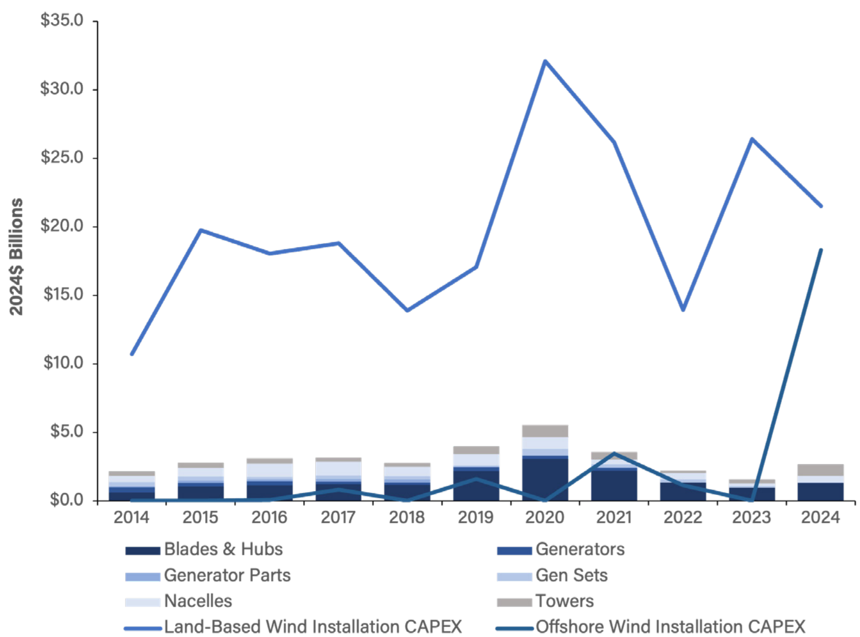
53 Photo courtesy of L.S. Cable & System

Wind Component Trade Flows

In 2024, the wind industry imported $2.7 billion of wind equipment across five product areas: blades & hubs (49%), generator parts (1%), generator sets (<1%), nacelles (19%), and towers (31%).[54] Towers and nacelles experienced the most significant increase in imports compared to the prior year, followed by blades & hubs. Generator set imports, however, continued to decline (Figure 19).

In prior years, imports closely tracked deployment volumes. However, this changed in 2024 due to the construction of Revolution Wind, South Fork, and the Coastal Virginia Offshore Wind projects. A similar uptick in tower imports in 2023 reflects the use of imported towers to top monopile installations at Vineyard Wind 1 and South Fork offshore wind projects. Domestic offshore wind manufacturing is more nascent than land-based wind. With more offshore wind components being imported in 2024 than in prior years, there has been a notable shift in top import countries.

Figure 19: Imports of Major Wind Components by Year [55]

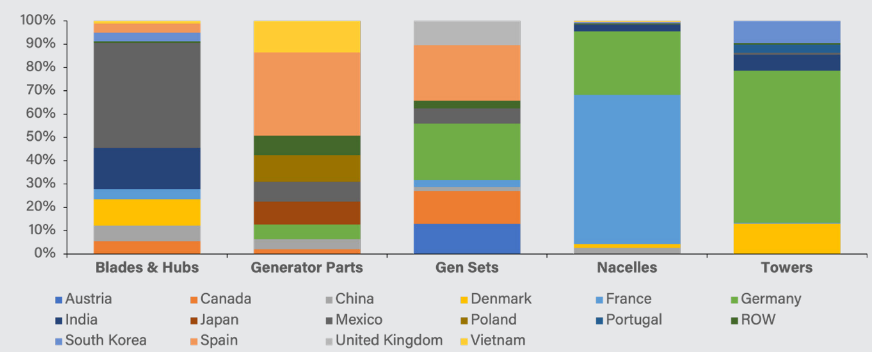


U.S. Wind Turbine Imports in 2024: A Shift in Leaders and Components

America's top wind trading partners remained largely consistent with 2023, with the top import countries being Germany, Mexico, France, India, Denmark, and South Korea (Figure 20). Germany overtook Mexico as the leading source, with $655 million in total wind component imports. South Korea entered the top five, narrowly surpassing Spain, with $125 million in imports. Together, these five countries accounted for over 86% of total U.S. wind component imports.

2. **Tower** imports saw the steepest growth in 2024, largely driven by Germany, which supplied $514 million. Nearly 80% of all U.S. wind tower imports came the country, many of which were destined for offshore installations.
3. **Nacelle** imports also rose significantly. France emerged as the top supplier, accounting for over 60% of nacelle imports, followed by Germany with 27%. Combined, the two countries contributed more than $450 million in nacelle imports headed, primarily, for offshore wind projects.
4. **Blades and hubs** remained the largest import category, totaling over $1.3 billion in 2024. Mexico, while still the top source, saw its share drop from 60% to 45% due to the drop in land-based wind installations in 2024. India remained the second-largest supplier at just under 18%.
5. **Generator components** increased 80% year-over-year but still made up just 1% of total imports, at $30 million. Generator sets declined further to $6 million. Spain and Vietnam were key suppliers of parts, while sets were primarily imported from Germany, Spain, and Canada.

Figure 20: Top 2024 Land-based and Offshore Wind Import Countries by Component[56]



54 For component definitions please see appendix.

55 USITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/

56 USITC harmonized trade codes do not disaggregate offshore wind components from land-based wind. This bar chart is representative of wind imports for both offshore and land-based wind collectively.

The wind industry has a diversified global supply chain that allows buyers to limit exposure to China with a more concentrated footprint in Europe and the Americas. Countries like Denmark, Germany, France, Mexico and Canada are the top sources of wind components, with some additional volume coming from India, Japan, and South Korea. However, based on the current Administration trade policy announcements, these countries all face elevated tariffs compared to prior years (Table 6).

Baseline MFN tariffs across wind components vary from 0-3% by country. Because all the tracked wind components contain some aluminum and steel content, all imports are assumed to be impacted by the Section 232 tariff on steel and aluminum, set at 25%. However, this is not applied to the value of the entire imported component, but only to value of steel and aluminum content contained in the imported product. In addition, the IEEPA rates vary by country and have been the topic of recent negotiations. China's rate was most recently negotiated to a 30% tariff rate, down from 145%. European imports will potentially be subject to 20% tariffs unless the U.S. and the EU negotiate a different reciprocal IEEPA tariff rate. Component imports from India may experience a 26% IEEPA tariff, while those from Mexico will face a 25% IEEPA tariff unless USMCA-compliant.

Chinese imported components are likely to be avoided in favor of lower-tariff countries or domestic sourcing alternatives. Because offshore wind manufacturing is more nascent in the U.S., these tariffs disproportionately impact the future of American offshore wind projects.

Table 6: Wind Component Trade Exposure as of April 2025 [57,58,59]

Component	Top Import Country	Base Tariff	Section 232	IEEPA	Total
Nacelle	France	3%	25%	20%	48%
	Germany	3%	25%	20%	48%
	India	3%	25%	26%	54%
	China	3%	25%	30%	58%
	Denmark	3%	25%	20%	48%
Towers	Germany	0%	25%	20%	45%
	Denmark	0%	25%	20%	45%
	South Korea	0%	25%	25%	50%
	India	0%	25%	26%	51%
	Portugal	0%	25%	20%	45%
Blades & Hubs	Mexico	0%	25%	25%	50%
	India	0%	25%	26%	51%
	Denmark	0%	25%	20%	45%
	Canada	0%	25%	25%	50%
	China	0%	25%	30%	55%
Gen Sets	Germany	2.5%	25%	20%	47.5%
	Spain	2.5%	25%	20%	47.5%
	Canada	0%	25%	25%	50%
	Austria	2.5%	25%	20%	47.5%
	United Kingdom	2.5%	25%	10%	37.5%
Generator Parts	Spain	3%	25%	20%	48%
	Vietnam	3%	25%	46%	74%
	Poland	3%	25%	20%	48%
	Japan	3%	25%	24%	52%
	Mexico	0%	25%	25%	50%

57 For IEEPA tariffs, while the announced reciprocal tariff rates are paused until July 8, 2025 pending negotiation with the Administration, the announced rates are used in this analysis for illustrative purposes.

58 All tariff information is rapidly evolving as trade negotiations are underway. All information is effective as of May 12, 2025 and subject to change as of publication.

59 Imports from Mexico and Canada are not subject to the 25% IEEPA fentanyl tariff if the imported production is USMCA-compliant, however the rate of 25% is assumed for illustrative purposes assuming non-compliance.

Energy Storage

The domestic grid battery storage manufacturing supply chain is a nascent but quickly growing industry. There are a wide variety of companies seeking to manufacture and provide energy storage technologies for the electric grid. This includes lithium-ion-based batteries that currently dominate the market for short- and mid-duration energy storage, as well as alternative battery technologies that utilize iron and zinc for long-duration and multi-day energy storage. For cell-based technologies, battery cells are manufactured by combining key components including cathodes, anodes, separators, electrolytes, and auxiliary materials. Cells are then combined into module packs, arranged in a specially designed and highly engineered container, tied to a power conversation unit (often referred to as an inverter) and safely regulated with secondary systems like the battery management system (BMS), thermal management system (TMS), energy management system (EMS) and other protection and electrical equipment.

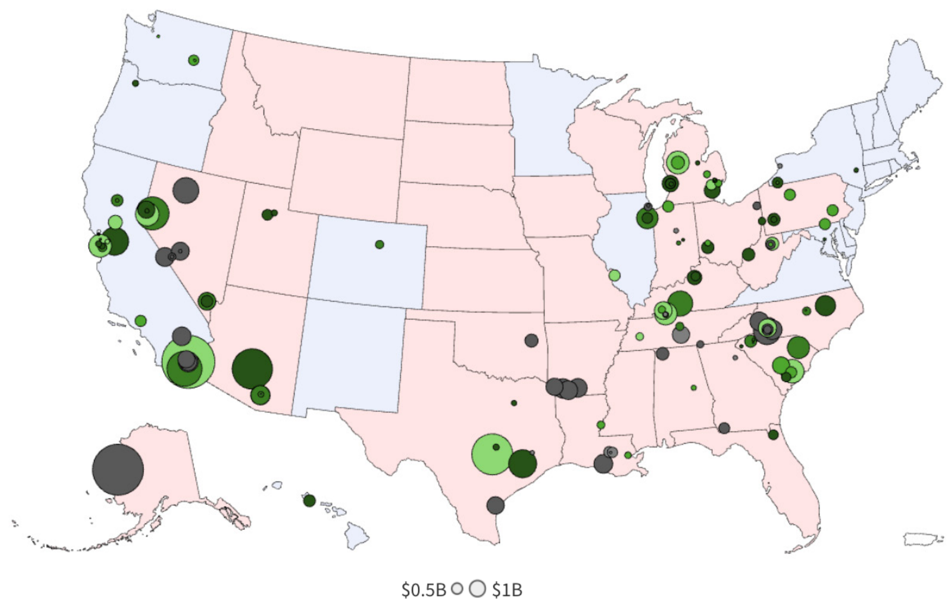
The primary steps in the battery energy storage supply chain are roughly segmented into the following: 1) upstream—mining and refining of metals and minerals; 2) midstream—processing of raw materials and production of cathodes, anodes, separators, and electrolytes; and 3) downstream—manufacturing of battery cells and modules. As record deployment of U.S.-based energy storage projects creates demand for domestically made battery energy storage components, the industry has seen significant progress in creating or expanding production of downstream components.

Domestic Energy Storage Manufacturing

The surge in domestic battery storage manufacturing industry was supported by two key congressional actions—the passage of the Bipartisan Infrastructure Law and the extension of federal clean energy tax credits to support accelerate energy storage deployment and grid battery manufacturing. As energy storage deployment grew more than 25x between 2019 and the Spring of 2025, over 180 new battery storage component manufacturing facilities had been announced and just a year later, in 2023, the first utility-scale battery module manufacturing plant was commissioned.

Similar to other energy manufacturing industries, the progression of battery storage manufacturing started at the module level before progressing upstream. Today, there are over 65 primary battery storage component manufacturing facilities and pilot projects in operation. This includes more than 20 module and nearly 10 cell facilities or expansions producing a range of battery chemistries. Further, there are nearly 40 facilities under construction and over 70 more in development. Based on current announcements, the industry is expected to have commissioned close to 180 primary component facilities by 2030 (Figure 21).

Figure 21: Grid Battery Energy Storage Manufacturing Facilities Online and Announced



Battery manufacturing projects span 38 states, of which 63% voted Republican in the 2024 presidential election. The states with the largest number of battery storage manufacturing facilities include: California (11%), Michigan (10%), and North Carolina (6%). Early movers in domestic battery manufacturing include companies such as Fluence, Form Energy, LG, and Tesla. From leading with advanced supply chain networks, vertical integration and breakthrough technologies, these manufacturers are changing the narrative around American battery production.

Lithium iron phosphate (LFP) cathode with graphite anodes is the dominant battery cell chemistry for short-duration grid energy storage applications. Emerging demand for complementary, longer-duration energy storage applications are supporting the commercialization of additional technologies such as Form Energy's 100-hour iron-air battery or Eos Energy's zinc-based battery, which represent additional opportunities for domestic supply chain investment.[60]

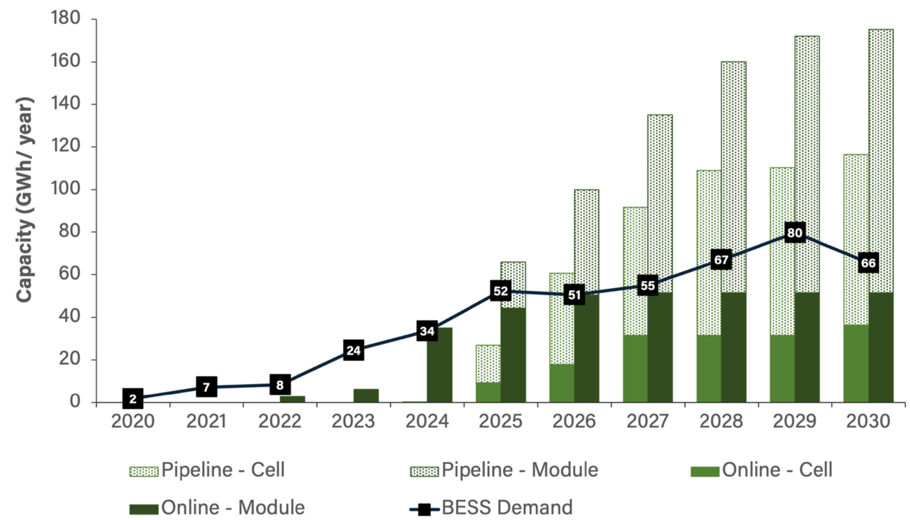
Table 7. Domestic Energy Storage Primary Component Manufacturing Incentives, Facilities and Expansions[61,62]

Components	45X Credit Amount	Online	Under Construction	In Development
Module	$10/kWh or $45/kWh[63]	6	6	6
Cell	$35/kWh	3	4	3
Cathode Active Material (CAM)	10% of production costs	3	2	4
Anode Active Material (AAM)	10% of production costs	5	3	8
Electrolyte	10% of production costs	4	2	6
Battery-Grade Lithium (processing)	10% of production costs	7	5	11
Battery-Grade Graphite (processing)	10% of production costs	5	2	4

Modules: Currently, there are 6 LFP battery module manufacturing facilities in operation capable of producing over 35 GWh of battery storage capacity for grid application per year.[64] There are more than 10 additional LFP module facilities in the pipeline, including more than 5 that are under construction. Once complete, the facilities under construction will add over an estimated 75 GWh of module capacity for battery storage.[63] If the rest of the projects in the pipeline proceed, domestic module capacity will increase to over 170 GWh by 2030 as seen in Figure 22.[63]

Cells: The industry is focused on establishing robust battery cell manufacturing capabilities. Currently, there are three LFP cell facilities operating— AESC in Tennessee, LG Energy in Michigan, and Lithion Battery in Nevada. These plants can produce close to 20 GWh of cells for battery storage with capacity anticipated to grow to over 35 GWh. Behind these facilities are three locations under construction that will add over 15 GWh of battery storage cell capacity, ramping to over 65 GW by 2030. Plants under construction include American Battery Factory's two-phase facility in Arizona, Gotion's Illinois plant, and Tesla's plant expansion in Nevada. Canadian Solar has announced an LFP cell plant to commission this year, adding approximately 6 GWh of production. Based on project announcements, LFP cell capacity at full capacity utilization, would exceed battery storage demand by 2026 (Figure 22).

Figure 22: Domestic Lithium Iron Phosphate BESS Downstream Manufacturing Pipeline[65,66]



60 Non-lithium ion capacity is not considered in the supply – demand figures of this section

61 ACP tracks capacity expansions and original capacity announcements individually, thus the number online, under construction and in development may exceed the number of physical manufacturing plants.

62 Module, Cell and CAM data only reflect LFP facilities and expansions. AAM reflect graphite anode facilities and expansions only.

63 $45/kWh rate is applicable only for module technology that does not require battery cells.

64 Capacity estimates are with respect to LFP battery storage capacity specifically.

65 Source: CPIQ, BNEF, Company Interviews, CEA

66 For capacity estimation methodology details please refer to Manufacturing Methodology

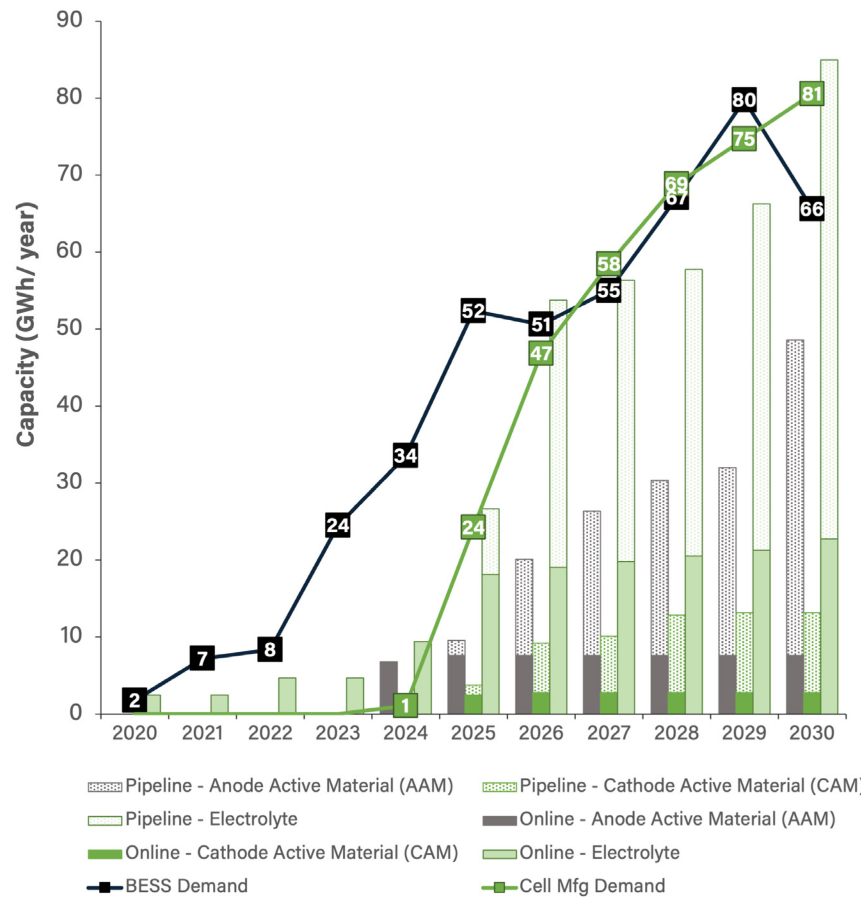
Midstream (Electrolytes, Cathodes, Anodes): The U.S. battery storage supply chain is expanding beyond cells and modules, with growing investment in midstream components like electrolytes, cathode active materials (CAM), and anode active materials (AAM). While domestic capacity is growing, midstream production remains below demand (Figure 23).

Electrolyte: There are 4 companies producing battery electrolyte domestically, with 2 more under construction and 5 announced facilities. Notably, Koura received a $100 million grant for its planned facility in St. Gabriel, Louisiana.[67] If all announced capacity comes online, domestic electrolyte production could meet projected BESS demand (Figure 23) by 2026.[68]

Cathode: U.S. production of LFP cathode material—the dominant battery chemistry—is currently limited though 6 companies have announced manufacturing facilities capable of delivering over 12 GWh volume of CAM for battery storage.[69] There is a lot of enthusiasm to develop domestic capabilities in this link of the supply chain, but proven scale remains limited. If all announced capacity is realized, a supply gap will remain.

Anode: Graphite anode production—both natural and synthetic—is expanding, with several companies launching or planning projects across multiple states.[70] Graphite is often blended for performance and cost reasons. China currently dominates global anode supply (75% of natural and 74% of synthetic graphite). U.S. firms face challenges competing on cost and quality, and qualification for battery-grade use remains a time-intensive barrier. In 2024, two AAM companies began producing graphite anodes. In future years, 10 companies intend to produce AAM in the United States in nine states, some processing natural graphite and others producing synthetic graphite which uses coal or crude as a typical feedstock.

Figure 23: Domestic Lithium-Ion BESS Midstream Manufacturing Pipeline [71,72]



67 U.S. Department of Energy (2024). Portfolio. Retrieved from: https://www.energy.gov/mesc/mesc-portfolio?filterFunding_Source_Facet=Battery_Materials_Processing_Grants_and_Battery_Manufacturing_and_Recycling_Grants

68 Available midstream supply to meet BESS demand has been reduced to consider competing EV demand.

69 Nickel-manganese-cobalt (NMC) is currently the dominant cathode chemistry for electric vehicles (EVs). However, there exists considerable demand for LFP batteries in the EV segment, competing against BESS for limited supply.

70 ACP recognizes that other anode chemistries are developing domestically but has chosen to focus this report on graphite anodes specifically.

71 Source: CPIQ, BNEF, Company Interviews, CEA

72 For capacity estimation methodology details please refer to Manufacturing Methodology.

Upstream: The upstream segment—including raw mineral extraction and processing—is undeveloped due to long permitting timelines and the limited domestic midstream industry that would serve as the primary customer base.

Graphite: The U.S. produces no natural graphite today and limited domestic reserves face economic uncertainty. Projects like GraphiteOne in Alaska (pre-feasibility stage) and early-stage prospects in Alabama may come online by 2029 but permitting among other delays remain a barrier.[73,74]

Synthetic graphite, derived from coal or crude, offers a potential domestic alternative. It is typically more energy intensive and costly than natural graphite, and the two materials are not an exact technical substitute; however, synthetic graphite is not limited by natural resource availability. Amsted Graphite and Birla Carbon are the only two synthetic graphite production facilities in the U.S. with three more under construction or in development.[75] Announced investment for developing domestic synthetic graphite totals about $2.5 billion. Novonix received a $103 million investment to establish North America's first battery-dedicated commercial synthetic graphite plant in Tennessee.[76]

If all announced natural and synthetic graphite capacity scales as planned, domestic output would well-exceed 35 GWh-equivalent for grid battery storage by 2030, which as seen in Figure 24, would fall short of meeting projected AAM manufacturing needs and total BESS demand.[77]

Lithium: The U.S. battery-grade lithium pipeline surged from a single ore producer (Albemarle) and two processing companies (Albemarle and Livent) to over 15 companies pursuing more than 20 prospective projects. If all announced production capacity is realized, domestic production could exceed grid battery energy storage demand by 2028. Federal tax credits have catalyzed this shift—Albemarle and ESM ATLiS both received 48C support for projects in Nevada and California, respectively.76 As seen in Figure 25 the U.S. could produce over 68 GWh-equivalent of lithium for grid energy storage applications by 2030 if all announced lithium projects reach commercial operation.

Figure 24: Domestic Lithium-Ion BESS Processed Graphite Manufacturing Pipeline[77]

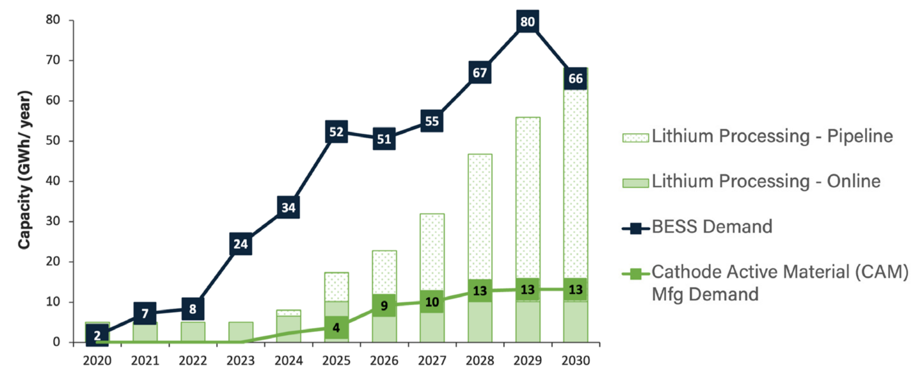
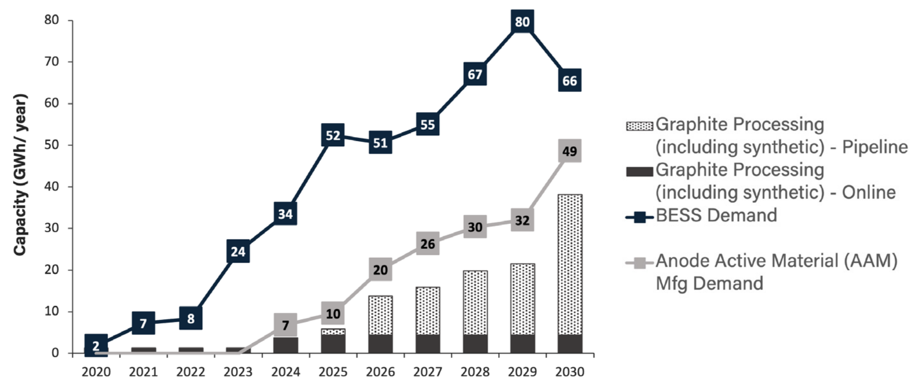


Figure 25: Domestic Lithium-Ion BESS Processed Lithium Manufacturing Pipeline [77]



73 S&P Global (September 13, 2024). "Graphite One to start permitting Alaskan mine development in spring 2025, construction in 2026." Retrieved from: https://cilive.com/commodities/metals-mining/news-and-insight/091324-graphite-one-start-permitting-alaskan-mine-development-spring-construction

74 National Mining Association (2021). "Delays in the U.S. Mine Permitting Process Impair and Discourage Mining at Home." Retrieved from: https://nma.org/wp-content/uploads/2021/05/Infographic_SNL_minerals_permitting_5.7_updated.pdf

75 Anovion Technologies, Novonix Anode Materials, and Epsilon Advanced Materials

76 U.S. Department of Energy (2024). Applicant Self-Disclosed 48C Projects. Retrieved from: https://www.energy.gov/mesc/applicant-self-disclosed-48c-projects

77 Available capacity for BESS is reduced to account for competing demand from EVs. See the appendix for methodology details.

Battery Storage Manufacturing in Action: Fluence

Fluence, a global market leader delivering intelligent energy storage systems, services, and asset optimization software, is committed to strengthening domestic manufacturing, reducing supply chain risk, and advancing U.S. energy security. With more than 23 GWh of battery energy storage capacity deployed or contracted across 80+ projects in the U.S., Fluence is supporting leading U.S. utilities, power producers, and developers with cutting-edge storage solutions that enable a more reliable and cost-effective grid.

Fluence has a growing network of U.S. manufacturing facilities, which play a crucial role in Fluence's strategy to onshore production of every major product and component of a grid-scale battery energy storage system to serve U.S. demand with domestically manufactured products. This network includes battery cells made in Smyrna, Tennessee; battery modules made in Erda, Utah; enclosures (made with U.S. steel) and battery management systems hardware made in Goodyear, Arizona; thermal management systems made in Houston, Texas; and an inverter supplier which manufactures in Simpsonville, South Carolina.

These manufacturing partnerships represent approximately $700M in investment and more than 1,200 manufacturing jobs, along with 450 construction jobs, in calendar year 2025 alone. That is expected to quickly grow, including approximately $350M in additional investment and 650 jobs in the next few years.

The expansion of Fluence's use of domestic manufacturing capabilities comes at a time of increased focus on energy security and U.S. supply chain resilience. The company's products should play a critical role in grid stability and power sector modernization, with energy storage projects contributing to grid reliability for 278 million Americans across 8 of the 10 U.S. ISO power markets.

Figure 26: Fluence's Battery Cell Manufacturing Plant in Tennessee[78]

Battery Storage Manufacturing in Action: EPC Power Corp.

Manufacturer, EPC Power Corp. ("EPC Power"), produces an integral component supporting clean energy supply chains— utility-scale inverters. The company produces BESS and solar inverters in its two plants in South Carolina and California.

EPC Power has invested $5 million to date in its Simpsonville, South Carolina manufacturing. With surging demand, they expect to invest an additional $14 million over 2025 and 2026. Currently, the Simpsonville plant employs 76 individuals which is anticipated to more than double over the coming years.

In Poway, California EPC Power has invested an estimated $11.5 million in its inverter manufacturing facility with plans for an additional $11 million investment. EPC Power's California facility offers employment to 150 workers. As manufacturing ramps, this location may further increase their workforce.

In sum, EPC Power has domestic inverter capacity of more than 5.6 GW_{dc} and has the potential to grow to over 11 GW_{dc} by 2026. EPC Power is not only adding crucial capacity to domestic solar and BESS supply chains but will offer manufacturing jobs to over 450 Americans. The company has expressed commitment to hiring locally as well as engaging in local volunteering, providing its employees with health care benefits and continued education opportunities. Partnering with the Simpsonville and Poway communities where EPC Power operates has played an integral part in the company's success.

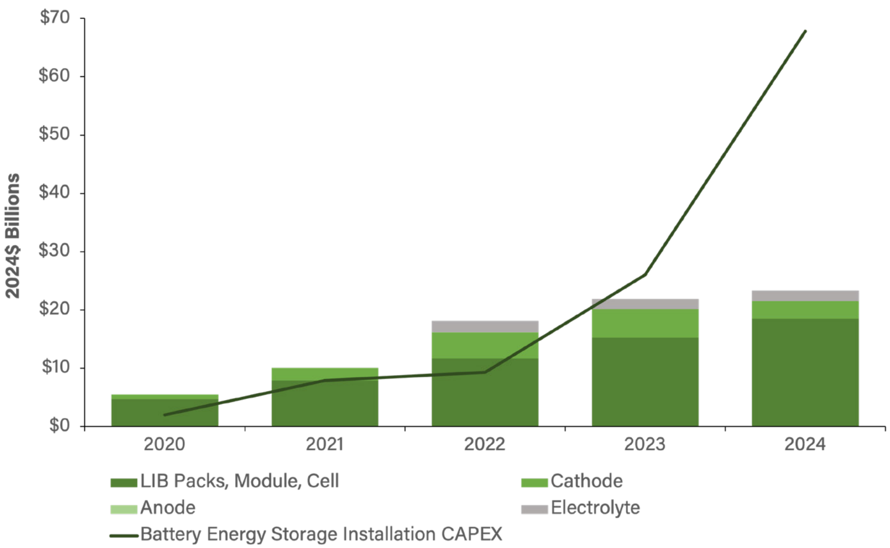
78 CIO Bulletin.2024.Available from: https://www.ciobulletin.com/clean-energy/fluence-energy-battery-manufacturing-domestic-production-energy-storage

Battery Storage Component Trade Flows

The industry imported a record $18 billion in non-EV lithium-ion battery components in 2024. However, the actual year over year growth in imports is slowing as domestic manufacturing ramps up to meet the growth of energy storage deployment. From 2022 to 2023 there was a 30% increase in imports compared to 22% from 2023 to 2024. ACP expects energy storage lithium-ion battery imports to decrease as domestic production capacity of module and cell manufacturing starts operating.

Electrolyte imports peaked in 2022 and fluctuated over 2023 and 2024. Imports are likely to decline in future years as planned U.S. electrolyte manufacturing comes online.

Figure 27: Lithium-Ion Battery Imports by Year[79,80]



While, historically, battery imports are predominantly sourced from China, this trend is reversing as domestic capabilities increase. In the short term, battery imports from rapidly diversifying global sources will be necessary to bridge supply for rapidly expanding energy storage deployment. The record pace of energy storage deployments to meet rising demand for electricity is the key driver for the current expansion of domestic grid battery manufacturing. Without ongoing growth in demand for battery energy storage projects, accelerated by federal energy tax credits, demand for American-made grid batteries will contract.

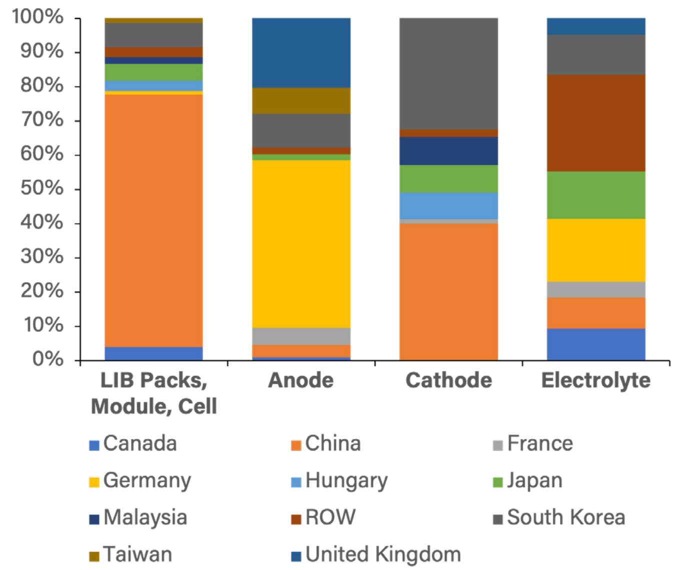
Using an additive approach, the data in Figure 27 shows that the U.S. is looking to both reshore and friend-shore capacity to ensure supply chain resilience. Notably, the percentage of Japanese and Canadian imports have risen over prior year volumes, over 10% and 260% respectively. In 2024 battery component imports decouple from the trend of rising battery installations; a testament to the impact domestic manufacturing is making to increase battery domestic content.

In 2024, the majority of imported cathodes were sourced from China, with South Korea a close second as seen in Figure 28. A smaller value was brought in from Malaysia, Japan and Hungary. Anode imports totaled just $43 million in 2024, much smaller than cathode electrode import volumes. Germany was the primary supplier. Processing of battery-grade graphite (used in the anode as a blend of both refined natural graphite and synthetic graphite) continues to be concentrated in China. The named electrode trade nations are all considered top trade deficit countries, thus targets for increased tariffs under the Trump Administration. Adding to the cost of input materials raises major concerns for domestic cell producers that have just commissioned or have yet to come online.

79 USITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/

80 The lithium-ion battery HTS codes referenced do not disaggregate between cell and module imports.

Figure 28: Top Origin Countries for Battery Component Imports in 2024 by HTS Code[81]



Electrolyte imports in 2024 were sourced from a more diverse subset of countries, most of whom had traditionally been considered U.S. allies and top trading partners. With respect to Germany and Japan, trade with between these nations and the U.S. has been governed by a range of agreements that have sustained a strong trade relationship in the past. Both countries are now potentially subject to additional tariffs imposed by the Trump Administration which are likely to undermine American battery cell manufacturing success by raising input costs.

The battery supply chain is subject to base (MFN) tariffs, Section 301 tariffs and various IEEPA tariffs (Table 8). For most components in the battery supply chain, base tariffs are imposed at rates of up to 3.4% based on the country and component. Section 301 tariffs are also applied to Chinese imports of battery modules and cells at 7.5% and for anode-grade natural graphite at 25%. IEEPA tariffs are then currently stacked on to both the base and 301 rates. While China faces a recently negotiated IEEPA rate of 30%, there will likely be significant challengers for importers of these products given the import origin of much of the battery supply chain is China. While Chinese tariffs are the most cost prohibitive, other key import countries like South Korea, Japan and Malaysia are currently facing up to 25% rate hikes unless trade negotiations can reduce their paused IEEPA tariffs.


Photo credit: Recurrent Energy

81 USITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/

Table 8: Battery Storage Tariff Implications as of April 2025 [82,83,84,85]

Component	Top Import Country	Base Tariff	Section 301	IEEPA	Total
Cells	China	3%	8%	30%	41%
	South Korea	0%		25%	25%
	Japan	3%		24%	27%
	Canada	0%		25%	25%
	Hungary	3%		20%	23%
Anode	Germany	0%		20%	20%
	United Kingdom	0%		10%	10%
	South Korea	0%		25%	25%
	Taiwan	0%		32%	32%
	France	0%		20%	20%
Cathode	China	3%		30%	33%
	South Korea	0%		25%	25%
	Malaysia	3%		24%	27%
	Japan	3%		24%	27%
	Hungary	3%		20%	23%
Electrolyte	Germany	3%		20%	23%
	Japan	3%		24%	27%
	South Korea	0%		25%	25%
	Canada	0%		25%	25%
	China	3%		30%	33%

Component	Top Import Country	Base Tariff	Section 301	IEEPA	Total
Anode Active Material (Natural Graphite)	China	0%	25%	30%	55%
	Canada	0%		25%	25%
	Mozambique	0%		16%	16%
Anode Active Material (Synthetic Graphite)	China	0%		30%	30%
	South Korea	0%		25%	25%
	Mexico	0%		25%	25%
	Japan	0%		24%	24%
	Germany	0%		20%	20%
Cathode Active Material (LFP)	Germany	3%		20%	23%
	China	3%		30%	33%
	Canada	0%		25%	25%
	United Kingdom	3%		10%	13%
	Brazil	3%		10%	13%

By imposing broad and lasting tariffs on input component imports across the supply chain over the next several years, the success of delivering expanded module and cell manufacturing in the U.S. is at risk. Without access to components and subcomponents while domestic capacity across the upstream, midstream, and downstream supply chain expands, pending American factories and manufacturing jobs will be lost. There will be cascading impacts, including delay and cancelation of otherwise shovel-ready energy storage projects that threaten national energy security and reliability.

82 For IEEPA tariffs, while the announced reciprocal tariff rates are paused until July 8, 2025 pending negotiation with the Administration, the announced rates are used in this analysis for illustrative purposes.

83 There is an active anode active material AD/CVD investigation underway. However, no tariff rates have been determined at the time of this report.

84 All tariff information is rapidly evolving as trade negotiations are underway. All information is effective as of May 12, 2025 and subject to change as of publication.

85 Imports from Mexico and Canada are not subject to the 25% IEEPA fentanyl tariff if the imported production is USMCA-compliant, however the rate of 25% is assumed for illustrative purposes assuming non-compliance.

02 CLEAN ENERGY MANUFACTURING ECONOMIC IMPACT

Photo credit: Nextracker

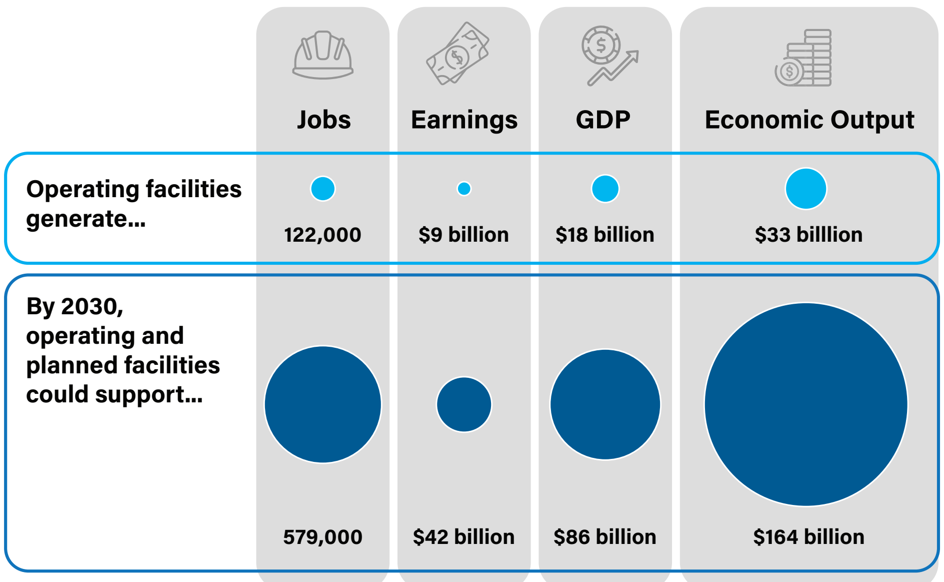
AMERICAN CLEAN POWER

CLEAN ENERGY MANUFACTURING ECONOMIC IMPACT

Current clean energy manufacturing activity supports 122,000 American jobs and contributes $33 billion annually to the American economy. Every clean energy manufacturing job supports three additional jobs in other related industries and every dollar earned in direct income generates $2.50 for the overall economy. If every announced facility in the comes online by 2030, clean energy manufacturing would increase its economic impact almost fivefold in just five years. Investing in American workers and infrastructure that bolster domestic clean energy manufacturing is a triple-win strategy: driving economic growth, creating good-paying jobs, and strengthening America's supply chain resilience.

Clean energy manufacturing's current and future potential economic impacts

Figure 29: Annual Economic Impact Summary



Existing Manufacturing Facilities

Annual operations from operating clean energy manufacturing facilities support 122,000 jobs, generate $9 billion in earnings, contribute $18 billion to Gross Domestic Product (GDP), and $33 billion in spending across the U.S. economy, as of 2024.[86] The domestic solar supply chain supports over 62% of total employment, 65% of earnings and GDP, and 60% of output. Land-based wind follows, contributing over a quarter of the economic impacts.

Table 9: Existing Clean Energy Manufacturing Facilities Annual Economic Impact by Technology

Tech Vertical	Employment	Earnings ($B)	GDP ($B)	Output ($B)
Solar	75,400	$5.9	$11.5	$19.4
Land-Based Wind	34,300	$2.4	$4.6	$9.5
Offshore Wind	700	$0.0	$0.1	$0.2
Batteries & Energy Storage	11,400	$0.8	$1.6	$3.5
Total	**121,800**	**$9.1**	**$17.8**	**$32.6**

86 These figures pertain to the primary component manufacturing facilities that ACP has validated. Unless otherwise noted, earnings, GDP, and output are expressed in billions of 2024 dollars and employment is rounded to the nearest hundred.

At the primary component level, solar modules dominate, accounting for roughly one-third of total economic impacts across clean power manufacturing (Figure 30). In contrast, the upstream and midstream segments for both solar and battery storage are more nascent. In solar, polysilicon and ingot/wafer production collectively support roughly 3,200 jobs—less than one-tenth the employment of solar module assembly. A similar pattern emerges in battery storage: anode and cathode active material manufacturing generate only slightly more than one-tenth the jobs of battery module assembly. Upstream activities, including mining and raw material processing, contribute less than 3% of the total jobs, earnings, and GDP impacts for battery storage, and less than 1% of total impact across all validated clean energy component facilities. These figures underscore a major imbalance in the domestic supply chain, with economic value heavily concentrated at the final assembly stage.

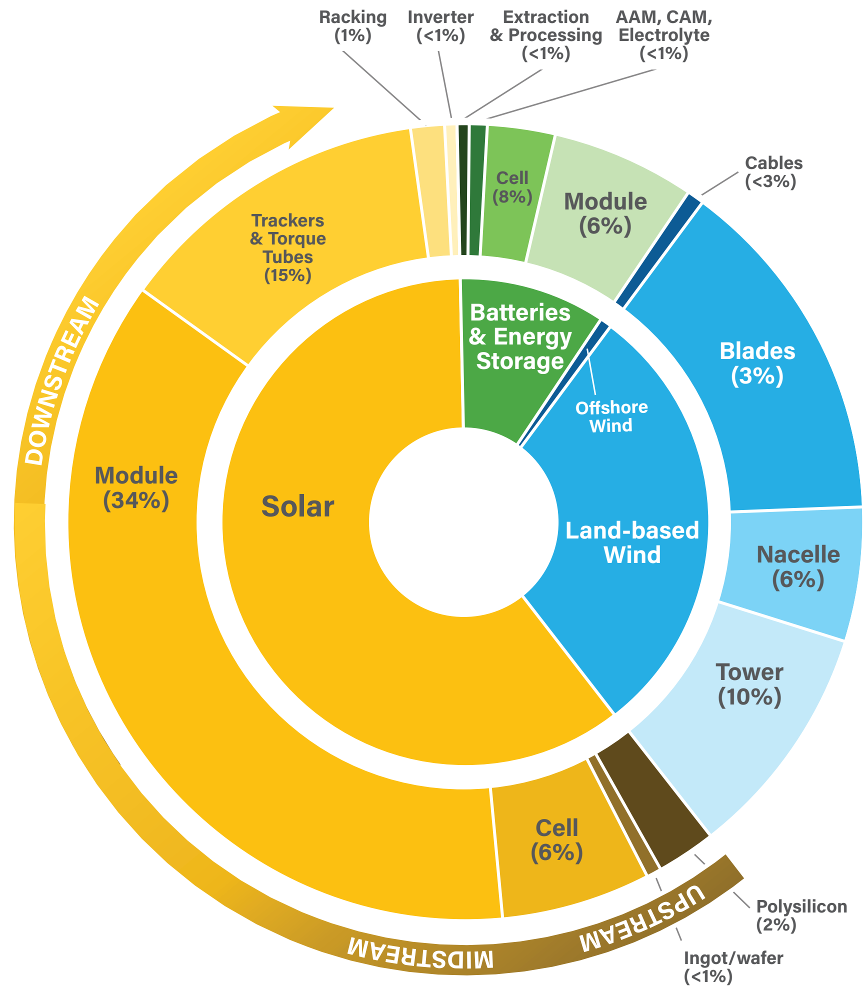
Land-based wind presents a more even distribution across its supply chain, with towers (10%), blades (13%), and nacelles (6%) each contributing meaningfully to total economic impacts. This suggests that, compared to solar and battery storage, wind manufacturing—particularly land-based—has a broader and more balanced domestic footprint.

Clean energy manufacturing is an excellent job generator. The sector directly employs 30,000 workers. For every direct job, one additional job is generated from upstream activities related to the initial economic activities (indirect job) and two additional jobs are generated from household spendings on income earned by these workers (induced job). Offshore wind and land-based wind have the highest employment multipliers, though battery storage and solar both have employment multiplier effects close to 4x.[87]

Table 10: Existing Clean Energy Manufacturing Facilities Annual Employment Impact by Impact Type

Tech Vertical	Direct	Indirect	Induced	Total	Multiplier Ratio
Solar	19,200	15,300	40,900	75,400	3.9
Land-Based Wind	7,800	10,000	16,500	34,300	4.4
Offshore Wind	100	300	300	700	>5.0
Batteries & Energy Storage	3,100	3,100	5,200	11,400	3.7
Total	**30,200**	**28,700**	**62,900**	**121,800**	**4.0**

Figure 30: Existing Clean Energy Manufacturing Facilities Annual Employment Impact by Primary Component



87 The direct employment figures for offshore wind and land-based wind are low in part due to certain components (e.g., hubs and monopiles) not being part of the primary component shortlist.

While the actual manufacturing jobs (represented as durable goods manufacturing in Figure 31 are only a quarter of total clean energy manufacturing employment they deliver higher economic value. They account for over one-third of all earnings and nearly 40% of the total GDP impact. **This means that direct goods manufacturing jobs of clean energy components contribute more to economic output and value-added GDP than the induced or indirect jobs.** They are a critical foundation for a competitive and resilient clean energy economy.

Figure 31: Existing Clean Energy Manufacturing Facilities Annual Impact by Industry Sector

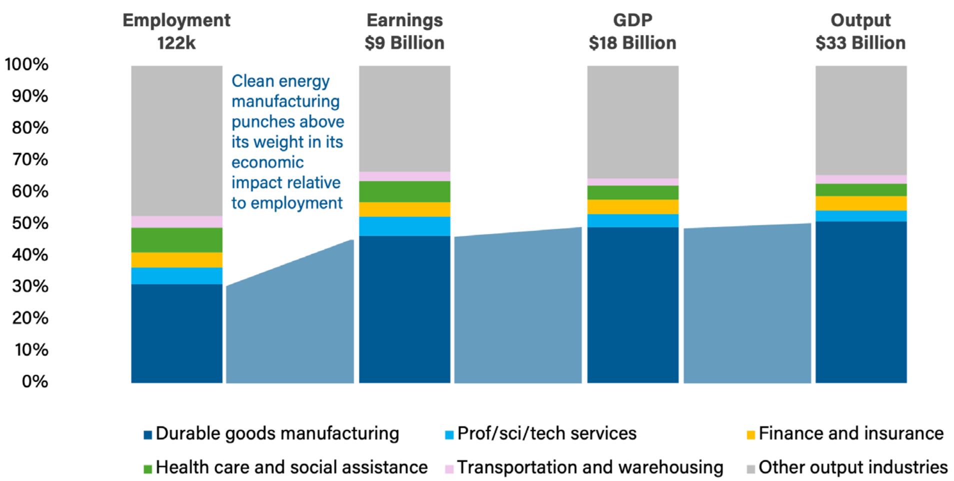



Photo credit: Nextracker

Creating Good Paying Jobs

Clean energy manufacturing is a high value-added sector offering salaries well above the national median wage. This is especially true in solar, where direct manufacturing job salaries averaged $134,000 in 2024, thanks in part to the higher relative wages in semiconductor manufacturing. Workers producing land-based wind components earned nearly $100,000 on average.

These high-quality manufacturing jobs also generate additional employment across the economy. Upstream supply chain jobs paid an average of $75,000, while downstream jobs supported by household spending—such as those in retail, food service, and hospitality—averaged about $52,000.

Looking across the broader labor impact, two trends emerge:

1. Clean energy manufacturing stimulates job growth across a diverse range of industries.
2. The clean energy manufacturing sector pays substantially better than most of the related sectors it supports—averaging at least $20,000 more in salary than even high-paying industries like professional and technical services.

In short, clean energy manufacturing not only creates jobs—it creates good-paying jobs that lift wages and generate broader economic value.

Figure 32: Average Earnings of Clean Energy Manufacturing Workforce Compared to the Average of all Workers[88]

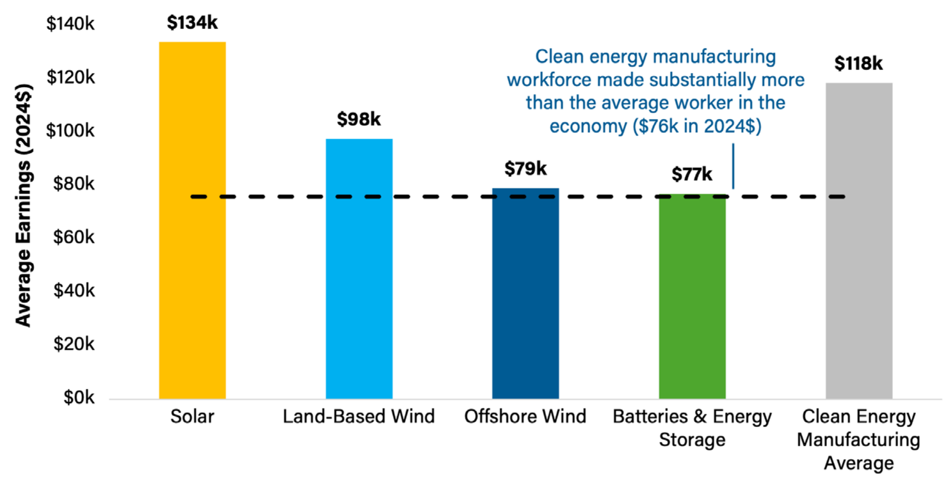
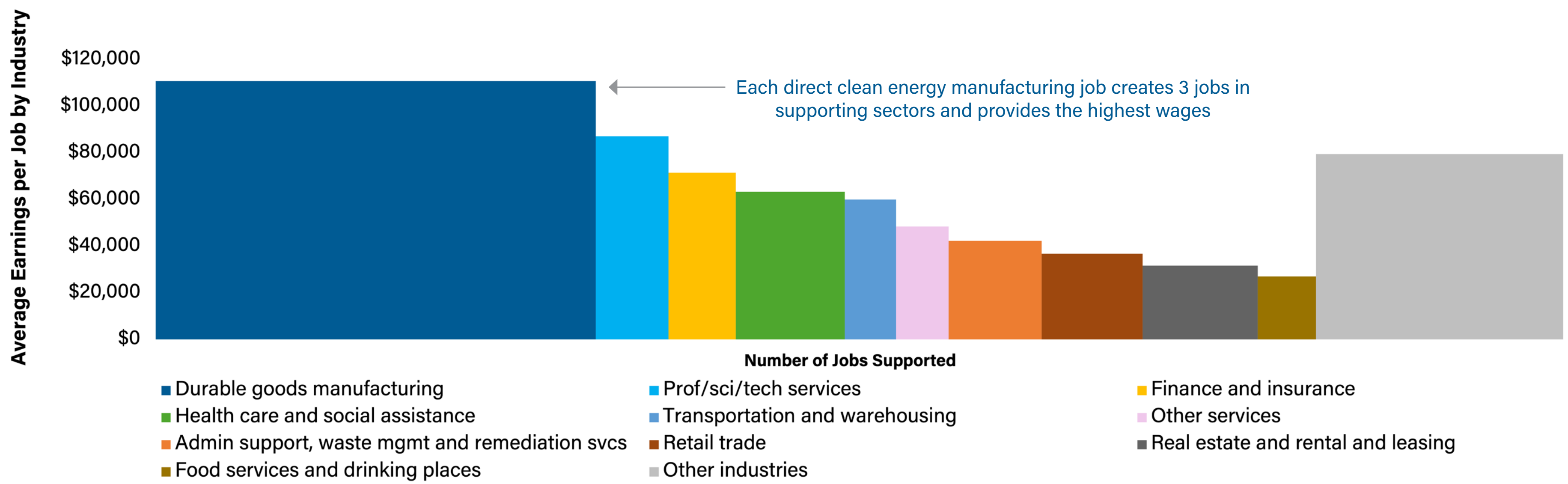


Figure 33: Annual Employment & Avg. Earnings by Industry Supported by Existing Clean Energy Manufacturing Facilities



88 Source: Bureau of Economic Analysis National Income and Product Accounts (NIPA) Tables Section 6 – Income and Employment by Industry. Tabulations are based on 2023 data (latest year available) and adjusted to 2024 dollars.

Construction Phase

Construction of new or expanded facilities also creates significant economic value. Since the IRA became law, a slew of new manufacturing facilities are breaking ground or existing facilities are expanding to meet unprecedented demand for clean power.[89]

Construction of new clean energy manufacturing facilities as well as the expansion, renovation, retrofitting, and repurposing of existing facilities in the past three years have supported 343,000 job-years.[90] Over 200,000 of these job-years stem from the construction of solar PV component manufacturing facilities. Battery energy storage followed with 74,000 job-years, followed by offshore wind (47,000) and land-based wind (11,000). Already over 40% (141,000) have already been fully realized as facilities have come online.

Figure 34: Construction Phase Employment (Job-Years) Since IRA's Passage by Technology and Status

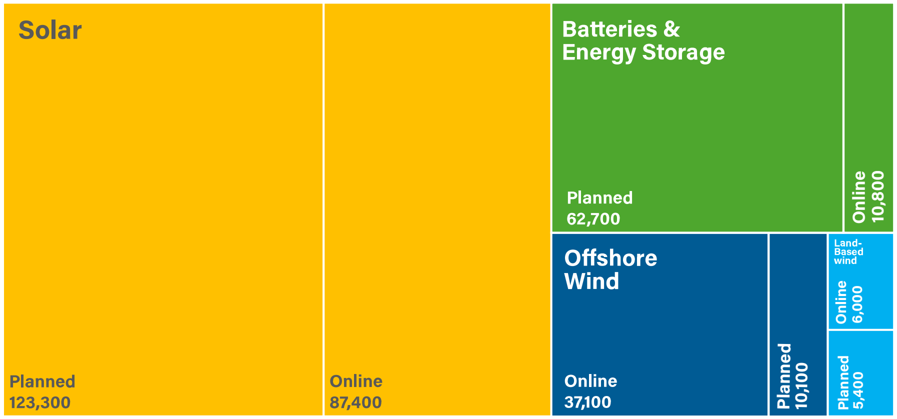


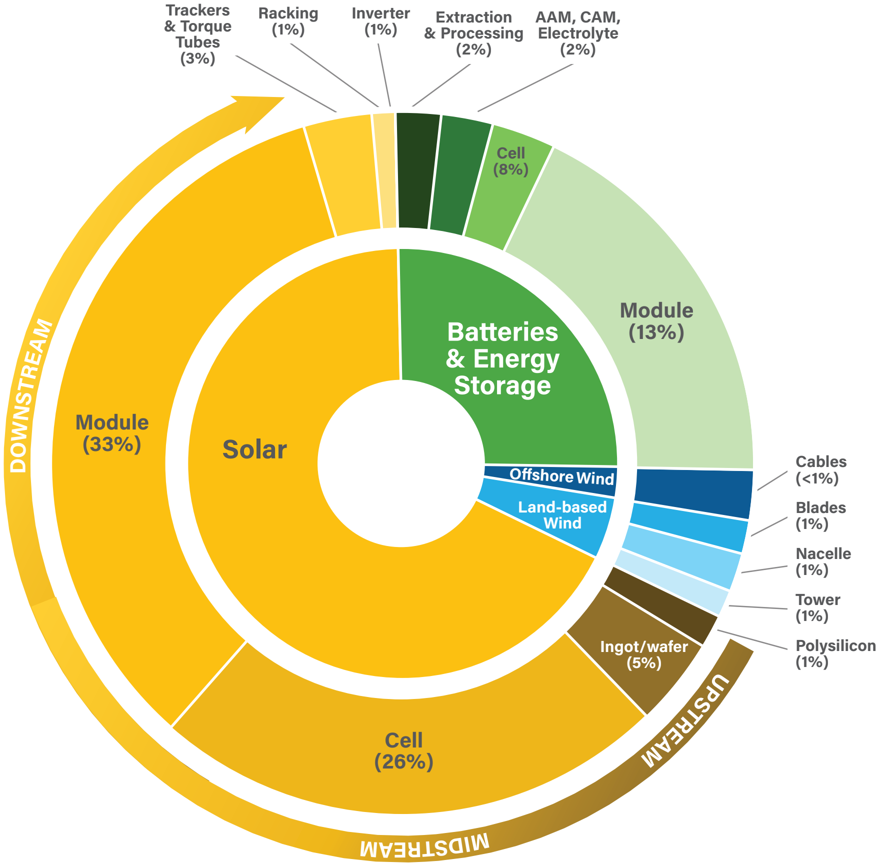
Table 11: Construction Phase Economic Impact by Technology Since IRA's Passage, Online & Planned Facilities

Tech Vertical	Employment	Earnings ($B)	GDP ($B)	Output ($B)	Earnings per job
Solar	210,700	$15.2	$22.6	$41.8	$72,400
Land-Based Wind	11,400	$0.9	$1.3	$2.4	$76,700
Offshore Wind	47,200	$3.7	$5.5	$10.1	$78,400
Batteries & Energy Storage	73,500	$4.8	$7.1	$13.1	$64,800
Total	342,800	$24.6	$36.5	$67.4	$71,700

The construction of these manufacturing facilities is estimated to create $25 billion in earnings, contribute $37 billion to GDP, and incentivize $67 billion in spending across the economy. The average earnings of the jobs range from $65,000 for the construction of battery & energy storage component facilities to $78,000 for the construction of offshore wind component manufacturing facilities with an industry average of $72,000.

Solar cells and module facilities make up over 50% of this under-construction economic impact. Energy storage cell and module facilities account for another 20%.

Figure 35: Construction Phase Impact by Primary Component Since IRA's Passage, Online & Planned Facilities



89 Construction timelines vary considerably depending on the technology, the components manufactured, state and local policies, and macroeconomic factors. For example, a polysilicon manufacturing facility (upstream solar PV supply chain), has a longer construction timeline than an ingot/wafer facility (midstream), which in turn has a longer timeline than a solar PV module assembly facility. Meanwhile, a cadmium-telluride solar PV cell manufacturing facility may have a shorter construction timeline than a polysilicon solar PV cell manufacturing facility. State- and local prevailing wage and permitting requirements could add considerable time to the construction timeline. Finally, in a rising interest environment, a construction project developer may face a higher financing hurdle, which may also add to the construction timeline. For these reasons, construction years are not modeled in this report.

90 Job-years is a metric that quantifies the economic impact of job creation over time (i.e., the cumulative number of jobs created over an undefined period). A project that employs 100 people over one year and a project that employs 50 people over two years both create 100 job-years. Note, not all of these jobs have been realized as some facilities are announced and have not entered the construction phase.

The construction of these facilities created 140,000 direct which supported an additional 51,000 job-years indirectly from upstream activities related to the initial economic activities and 152,000 job-years from household spendings on income earned by these workers (Table 12). The actual construction of these facilities makes up the largest share (41%) of total "construction phase" employment impacts (Figure 36). Real estate, retail trade, and health care and social assistance followed, each with about 7% of total job impacts.

Table 12: Construction Phase Employment Impact by Impact Type

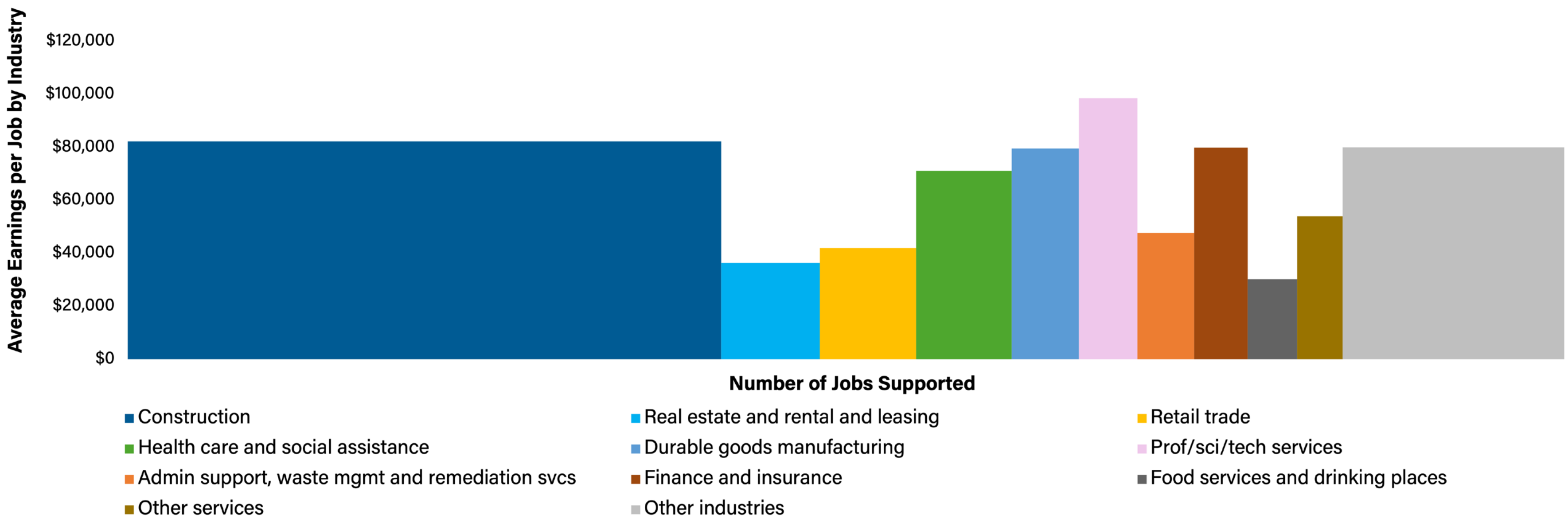
Tech Vertical	Direct	Indirect	Induced	Total
Solar	86,200	31,200	93,300	210,700
Land-Based Wind	4,600	1,700	5,000	11,300
Offshore Wind	19,300	7,000	20,900	47,200
Batteries & Energy Storage	30,100	10,900	32,600	73,600
Total	**140,200**	**50,800**	**151,800**	**342,800**

Within just the last few years, these investments have already delivered a robust return to the economy. In the past three years, the completed construction of clean energy manufacturing facilities generated 141,000 job-years, $10 billion in earnings, $15 billion in GDP, and $28 billion in output.

Table 13: Construction Phase Economic Impact by Now Online Facilities Since IRA's Passage

Tech Verticals	Employment	Earnings ($B)	GDP ($B)	Output (B)
Solar	87,400	$6.7	$9.9	$18.4
Land-Based Wind	6,000	$0.4	$0.6	$1.1
Offshore Wind	37,100	$2.4	$3.5	$6.5
Batteries & Energy Storage	10,800	$0.8	$1.1	$2.1
Total	**141,300**	**$10.2**	**$15.2**	**$28.0**

Figure 36: Job-Years & Avg. Earnings by Industry Supported by the Construction of Clean Energy Manufacturing Facilities



Impact of Future Facilities and Expansions

There are over 200 manufacturing facilities in the pipeline representing over $150 billion of investment. In the scenario where all these planned facilities become operational by 2030, clean energy manufacturing could support over half a million jobs, generate over $40 billion in earnings, contribute $86 billion to GDP, and add $164 billion in output to the economy annually. This is a 5X increase on the current economic impact of the sector.

Table 14: Existing and Future Clean Energy Manufacturing Facilities Annual Economic Impact, 2030, by Technology

Tech Verticals	Employment	Earnings ($B)	GDP ($B)	Output (B)
Solar	242,600	$19.7	$39.0	$62.9
Land-Based Wind	43,700	$3.1	$6.0	$12.3
Offshore Wind	2,700	$0.2	$0.3	$0.8
Batteries & Energy Storage	290,000	$19.1	$41.0	$88.2
Total	**579,000**	**$42.1**	**$86.4**	**$164.1**

Given announcement trends, manufacturing employment in battery and energy storage is expected to overtake solar.

Even if none of the new facilities in the pipeline are realized existing facilities will continue to ramp production. In this scenario, the sector is expected to grow from 122,000 jobs to support over 200,000 jobs. Additionally, it would deliver $15 billion in earnings and contribute $31 billion to GDP while spending $58 billion across the economy.

Table 15: Existing Clean Energy Manufacturing Facilities Annual Economic Impact by 2030, by Technology (accounting for announced production line ramping).

Tech Verticals	Employment	Earnings ($B)	GDP ($B)	Output ($B)
Solar	104,800	$8.3	$16.3	$27.0
Land-Based Wind	34,300	$2.4	$4.6	$9.5
Offshore Wind	700	$0.0	$0.1	$0.2
Batteries & Energy Storage	72,200	$4.8	$10.2	$22.0
Total	**212,000**	**$15.5**	**$31.2**	**$58.7**

If all announce projects come online by 2030, the combined impact of existing plus announced manufacturing activity is estimated to employ 150,000 workers directly, which will support 137,000 additional jobs from the upstream effects and almost 300,000 jobs induced by household spending of earnings. The job-multiplier is expected to reduce slightly from 4.0 to 3.8, given that batteries & energy storage has the lowest job-multiplier but the most explosive growth.

Figure 37: Existing & Pipeline Primary Clean Energy Manufacturing Facilities Annual Employment Impact in 2030

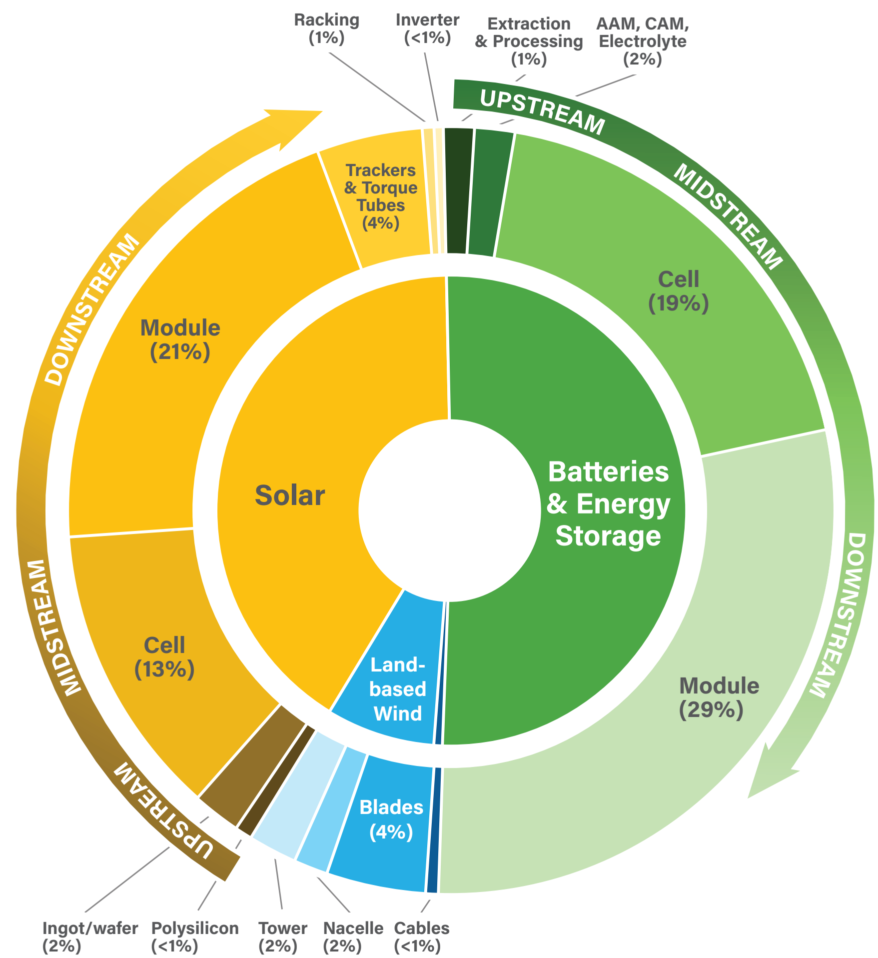


Table 16: Existing and Future Clean Energy Manufacturing Facilities Annual Employment Impact, 2030, by Impact Type

Tech Vertical	Direct	Indirect	Induced	Total	Multiplier Ratio
Solar	61,500	44,500	136,600	242,600	3.7
Land-Based Wind	9,600	12,900	21,200	43,700	5.0
Offshore Wind	500	900	1,200	2,600	4.5
Batteries & Energy Storage	78,800	78,500	132,700	290,000	3.9
Total	**150,400**	**136,800**	**291,700**	**578,900**	**3.8**

The economic and workforce impacts outlined here reflect only the initial wave of clean energy manufacturing investments. With continued policy support and sustained private-sector momentum, future announcements have the potential to significantly deepen these impacts. While the U.S. wind supply chain—especially for land-based wind—is relatively more established than solar or storage, it remains a critical pillar of domestic clean energy manufacturing. Ongoing investments in modernization, offshore wind components, and grid integration can help ensure wind continues to play a strong role in the next chapter of growth. Meanwhile, solar and battery storage present significant opportunities to expand the domestic supply chain and unlock new economic value.

Photo credit: Form Energy

03 ACHIEVING AMERICAN LEADERSHIP IN THE CLEAN ENERGY SUPPLY CHAIN

ADVANCING CLEAN ENERGY SUPPLY CHAIN SECURITY: POLICY PRIORITIES

U.S. clean power is primed to lead a revitalized, modern American manufacturing sector well into the next decade, but maintaining the momentum will require sustained policy stability. Downstream product manufacturing – such as solar modules, battery cells and wind nacelles – have expanded swiftly and are attracting follow-on investments in midstream and upstream segments like solar cells, lithium processing and other manufacturing inputs. A renewed commitment towards key Federal clean energy programs and stable, strategic trade policy ensures manufacturing businesses continue executing on ambitious reshoring plans, investing in local communities and hiring hundreds of thousands of American workers.

The Trump Administration and Congress can build on their historic American manufacturing legacy with a suite of targeted policy tools that include:

- **Preserving Energy Tax Credits (45X, 45Y, 48C, 48E):** The Advanced Manufacturing and Technology-Neutral tax credits for solar, wind and energy storage have been the critical driver for the $33 billion of annual domestic spending and 122,000 jobs generated by new domestic clean energy manufacturing. The Advanced Manufacturing Production Tax Credit ("45X") creates critical long-term investment security for domestic manufacturers to compete against foreign-sourced products. The Technology-Neutral Investment and Production Tax Credits ("ITC/PTC") ensure that domestically built energy products have an attractive domestic market to sell into, with supplemental policies like the domestic content bonus adder further supporting the use of U.S.-made goods.
- **Creating a Stable and Strategic Trade Environment:** Trade policy must facilitate market stability. Tariffs require a strategic approach with clear timelines to allow continued certainty for American businesses and the economy. When tariffs are used to counter unfair trade practices, they must be phased in over time and be sector-specific to avoid inadvertently raising costs and suppressing demand for American businesses, including domestic manufacturers. Equally important is the strategic expansion of international supply partnerships—with allies that meet high labor and environmental standards—to diversify sourcing and reduce exposure to geopolitical risks.
- **Facilitating a True All-of-the Above Energy Strategy:** Energy demand from artificial intelligence (AI), data centers and domestic manufacturing will create skyrocketing energy demand. ACP estimates that the U.S. will require up to 50% more power on the grid in the next 15 years. Traditional energy sources, while necessary, are not enough to meet near-term needs. Solar, wind and energy storage are immediately available and will ensure that the cost of U.S. energy – including costs for energy-intensive domestic manufacturing processes – remains low and support the overall competitiveness of American manufacturers and businesses.
- **Streamlining Permitting will Benefit Domestic Manufacturers and their Customers:** Permitting reform remains a barrier to timely project deployment, including both new manufacturing and material processing facilities and new clean energy deployments using domestically made products. The Administration and Congress should establish clear, predictable, standardized permitting timelines across agencies and technologies, streamline permitting processes, align judicial review requirements (e.g., FAST-41) for manufacturing and energy projects with other sectors, and expedite high-impact transmission projects.
- **Ensuring Executive Orders on Energy and Critical Minerals Security Appropriately Leverage Demand from Downstream Manufacturers:** Key critical minerals required for national security and advanced military equipment require diverse end markets for commercial scale and viability. Supporting robust deployments of grid-scale clean power and domestic manufacturing creates crucial private, commercial opportunities for domestic processors of key minerals like graphite, lithium, indium and tellurium. This reduces the government's cost of maintaining secure supply chains. Utilizing policy tools like the Defense Production Act while maintaining stable clean power deployments can facilitate private industry efforts to boost the purchase of qualified domestically sourced or processed critical minerals.

The U.S. clean power industry is building a more secure, more competitive and more American energy landscape, through flexible, resilient and affordable solar, wind and energy storage meeting surging demand with products built in domestic manufacturing facilities. With bold leadership, the U.S. can continue unleashing American energy dominance by necessarily harnessing and supercharging clean power's incredible domestic scale and strength.

ACP FUTURE CONSIDERATIONS

ACP acknowledges the supply chain segments of focus in this report do not cover a cradle-to-grave assessment of the critical utility-scale solar, battery storage and wind supply chain. Nor has this report sufficiently covered the importance of circularity in these supply chains. To reduce waste and preserve critical upstream materials within domestic borders, second life and recycling of clean energy components is essential. As domestic supply chains continue to build out and additional information on capacities and costs become available, ACP hopes to expand the scope covered in the manufacturing reports. Potential segments to be covered include but are not limited to those listed in Table 17.

Table 17: Future Scope Considerations

Offshore Wind	Monopiles
Onshore Wind	Hubs
Battery Energy Storage	Enclosures
	Separator
	Foils – Copper and Aluminum
	Battery Recycling
	Mineral Extraction
Utility-Scale Solar	Solar Glass
	Junction Box
	Diamond Wire Saws
	Backsheet
	PV Recycling
Technology Neutral	Cement
	Copper Extraction & Processing
	Steel
	Iron
	Aluminum
	Manufacturing Equipment


Photo credit: Vestas

APPENDIX

List of Acronyms

AAM	Anode Active Material
AD/CVD	Antidumping and Countervailing Duties
BESS	Battery and Energy Storage Systems
BIL	Bipartisan Infrastructure Law
BNEF	Bloomberg New Energy Finance
CAM	Cathode Active Material
CdT	Cadmium Telluride
CEA	Clean Energy Associates
CHIPS	CHIPS and Science Act
COGM	Cost of Goods Manufactured
c-Si	Crystalline Silicon
DPA	Defense Production Act
EIA	Energy Information Administration
EV	Electric vehicle
FAST-41	Title 41 of Fixing America's Surface Transportation Act
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GW	Gigawatt
GWh	Gigawatt-hour
HTS	Harmonized Tariff Code
IEEPA	International Emergency Economic Powers Act
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
kVA	Kilovolt-Amperes
LFP	Lithium Iron Phosphate
MFN	Most-Favored-Nation
MW	Megawatt
NREL	National Renewable Energy Laboratory
PTC	Production Tax Credit
USITC	U.S. International Trade Commissions
USMCA	U.S.-Mexico-Canada Agreement
W_{dc}	Watt (direct current)

Manufacturing Methodology

For this report, ACP has focused on specific components across the utility-scale solar, battery energy storage, and wind supply chains to offer insight into key components necessary for clean energy manufacturing. Table A1 refers to the components within each supply chain that will be discussed in greater detail. While this list omits several of the supply chain segments noted in the diagrams from the main body of the report, ACP recognizes that these components are critical and are subject to further research to be covered in future analysis.

Table A1: Scope of ACP Supply Chain Assessment 2025

Tech Vertical	Primary components
Solar PV	Module
	Trackers
	Racking
	Inverter
	Cell
	Ingot/Wafer
	Polysilicon
Batteries & Energy Storage	Module
	Cell
	Anode Active Material (AAM)
	Cathode Active Material (CAM)
	Electrolyte
	Extraction & Processing - Lithium
	Extraction & Processing - Graphite
Offshore Wind	Vessel
	Cables
Land-Based Wind	Nacelle
	Blades
	Tower
	Cables

ACP uses publicly available data as of April 28, 2025 to inform its manufacturing capacity estimates and economic impact analysis. Where there are gaps in information, ACP utilizes unit multipliers created using existing data points, specific to each sector and in most cases the specific components. Unless specific details are provided, to approximate capacity ramp-up, the assumed annual capacity corresponds to the year and quarter a project is online or expected online. In instances where the quarter is not provided, half of the announced capacity is used in year one of the expected production.

For the solar supply chain, ACP has focused on capacity specific to utility-scale solar. For facilities and expansions that produce components for utility, commercial, and residential solar, capacity is reduced by the estimated market share of utility-scale solar from S&P Global's *2025 Demand Study.*[8]

An additional ~50% capacity reduction is applied to polysilicon, to account for semiconductor industry demand competition.[91]

For the battery supply chain, a similar methodology is used to identify capacity available to utility-scale energy storage as opposed to electric vehicles (EV). Where there is joint manufacturing for BESS and EV, a capacity reduction is applied using estimates for domestic demand proportion. For all mid- and up-stream supply chain capacity, 11% is assumed to satisfy BESS demand based off NREL estimates.[92] Note that NREL's study combines BESS and consumer batteries in the 11% resulting in a slight overestimate of available capacity. For downstream segments, module and cell, a more generous percentage of capacity was allocated due to the omission of facilities dedicated to EV.[93]

91 Source: CEA

92 V. Putsche and M. Mann (2024). Global Supply Chain Flows. NREL. Retrieved from: https://mmac.energy.gov/research/global-supply-chain-flows

93 Source: member data

Trade Flow Methodology

Using the U.S. International Trade Commissions database, imports for consumption were pulled for a variety of harmonized trade codes (HTS). All trade codes that were leveraged and their associated supply chain component are listed in Table A2, below.

Table A2: Trade Codes by Sector[94]

Solar	
HTS	**Component**
8541.43.0080	Module - Thin-Film
8541.43.0010	Module - C-Si
8541.42.0010	Cell - C-Si
Onshore Wind	
HTS	**Component**
8503.00.9570	Nacelle
7308.20.0020	Tower
8412.90.9081	Blade & Hub
8502.31.0000	Gen Set
8503.00.9546	Generator Parts
Offshore Wind	
HTS	**Component**
8503.00.9570	Nacelle
7308.20.0020	Tower
8412.90.9081	Blade & Hub
8502.31.0000	Gen Set
8503.00.9546	Generator Parts
Batteries	
HTS	Component
8507.60.0020	LIB Packs & Modules
8507.60.0020	Cell
8507.90.8000	Cathode
8545.19.4000	Anode
3824.99.9397	Electrolyte

For the solar section, 5 component types were tracked and USITC categorized by HTS description as follows[95]:

- **Modules:** The original HTS code for solar modules was technology agnostic. It was later disaggregated by chemistry-type into two HTS codes specific to thin film and crystalline silicon modules.
- **C-Si Solar Modules:** Crystalline silicon PV cells assembled into modules or panels.
- **Thin Film Solar Modules:** Other PV cells assembled into modules or panels.
- **C-Si Solar Cells:** Specifically made of crystalline silicon.

For the wind section, six component types are tracked and represent combined imports for offshore and onshore wind using the USITC DataWeb HTS codes, defined as:[95]

- **Blades & Hubs:** Wind turbine blades and hub components for both land-based and offshore wind.
- **Generator Parts:** Other generator parts for AC generators including alternators, fuel systems, voltage regulators, cooling systems and components not otherwise specified for all generator types, not exclusive to wind generation.
- **Generators:** AC generators with output exceeding 750 kVA for wind-powered generating sets.
- **Generator (Gen) Sets:** Wind-powered electric generating sets which combine an engine and generator for all gen set types, not exclusive to wind generation.
- **Nacelles:** Electrical machinery and equipment parts of wind-powered generating sets for both land-based and offshore wind.
- **Towers:** Towers and lattice masts of iron and steel, tubular, whether or not tapered, and sectional components, thereof, for both land-based and offshore wind.

94 U.S. ITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/

95 USITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/

For the battery section, four component types are tracked and USITC defines the HTS codes analyzed as follows:[96]

- **Lithium-Ion Battery Packs, Module and Cell:** Electric storage batteries, specifically lithium-ion understood to include packs, modules and cell subcomponents.
- **Cathode:** Parts of storage batteries, excluding lead acid batteries, thus not specific to lithium-ion batteries. This category includes battery electrode components as well as battery separator.
- **Anode:** Lithium-ion storage batteries not either specified or included in prior categories. This category includes battery electrode components as well as battery separator.
- **Electrolyte:** Chemical products and preparations and residual products of the chemical or allied industries. This category is one of the many broad reaching categories that encompasses several component types beyond battery-specific components.

The USITC DataWeb was used to identify countries with the largest trade deficit (imports for consumption of a country exceed U.S. exports to the country) as shown in Table A3. The countries with historical free trade agreements (FTA) are denoted in **green**.[96]

Table A3: Top 25 Trade Deficit Countries in 2024 [97]

1	China	$ (295,401,646,638.00)
2	Mexico	$ (171,809,239,538.00)
3	Vietnam	$ (123,463,000,688.00)
4	Ireland	$ (86,748,222,126.00)
5	Germany	$ (84,823,644,956.00)
6	Taiwan	$ (73,927,165,468.00)
7	Japan	$ (68,467,721,077.00)
8	South Korea	$ (66,007,396,702.00)
9	Canada	$ (64,192,303,669.00)
10	India	$ (45,663,780,610.00)
11	Thailand	$ (45,608,930,737.00)
12	Italy	$ (43,964,484,856.00)
13	Switzerland	$ (38,463,331,684.00)
14	Malaysia	$ (24,830,097,128.00)
15	Indonesia	$ (17,882,642,164.00)
16	France	$ (16,382,885,870.00)
17	Austria	$ (13,097,807,738.00)
18	Cambodia	$ (12,340,177,232.00)
19	Sweden	$ (9,808,353,253.00)
20	Hungary	$ (9,443,007,518.00)
21	South Africa	$ (8,836,787,656.00)
22	Slovakia	$ (7,634,615,614.00)
23	Israel	$ (7,425,449,889.00)
24	Bangladesh	$ (6,151,802,185.00)
25	Slovenia	$ (5,960,837,151.00)

96 Japan is shaded in green as there is an existing critical minerals, specific trade agreement in place with the country. Mexico and Canada are also shaded in green as a result of the U.S.-Mexico-Canada Agreement (USMCA).

97 USITC DataWeb. 2025. Available from: https://dataweb.usitc.gov/trade/search/Balance/HTS

Economic Impact Methodology

Economic Impact Estimates

The Regional Input-Output Modeling System (RIMS II), developed by the Bureau of Economic Analysis, is an input-output (I-O) model used to quantify the economic impact (i.e., direct, indirect and induced effects) generated during the construction phase of the project and the impacts produced by the annual operations once the manufacturing facility is operational. Regional I-O accounts such as RIMS II are based on a detailed set of industry accounts that measure the goods and services produced by each industry and the use of these goods and services by industries and final users.

I-O accounts organize producers into n industries, where businesses in an industry are assumed to use the same production process. Each industry (i) produces gross output (X_i), measured in dollars. This output is sold to industries j as intermediate inputs (z_{ij}), or to final users (Y_i):

$$X_i = z_{i1} + z_{i2} + z_{i3} + \ldots + z_{in} + Y_i$$

Note that this assumes that production takes place under strict linear conditions. There exists a set of relationships called technical coefficients (a_{ij}) that shows how much of industry i's output is required to produce a dollar of output in industry j:

$$a_{ij} = z_{ij} / X_j$$

These coefficients show how I-O models assume that industries always use the same proportions of inputs to produce output.

Actual impacts may vary, depending on endogenous (e.g. production levels) and exogenous (e.g. final demand) factors and some impacts may not materialize due to unanticipated events and changing circumstances. The data and assumptions used in this study are subject to marginal uncertainty and variation and are based on the project parameters as of April 28, 2025.

Final demand multipliers are used to produce for the following economic metrics: Employment, earnings, GDP, and output. Additionally, direct multipliers are applied to calculate direct, indirect, and induced employment and earnings. These effects are generally defined as follows:

- **Employment:** A full-time equivalent (FTE) job is 2,080 hours/year. For employment impact related to the construction phase of the analysis, it is expressed in job-years as the construction timeline varies considerably for each project.
- **Earnings:** Compensation of employees plus the net earnings of sole proprietors and partnerships excluding personal contributions to social insurance programs and employee pension plans
- **GDP:** Gross domestic product, also referred to as value-added, is the market value of final goods and services produced in an economy
- **Output:** The total market value of industry sales, which is equal to GDP plus intermediate inputs.
- **Direct impact:** The initial change in economic activity in a specific final-demand industry or industry sector.
- **Indirect impact:** Also referred to as the upstream effect, results from industry-to-industry transactions required to support direct activity.
- **Induced impact:** Change in economic activity resulting from the changes in spending by workers whose earnings are affected by a final-demand change.

The appendix provides the employment impact of existing facilities by top states. It should be noted that the state-level results are based on the location of the facility. The state-level results should not be interpreted as, for example, the number of jobs that exist in a state, as it is likely that depending on economic and workforce factors such as local workforce availability, and state and local level policy requirements, a portion of the economic impact takes place out of state.

Construction Cost Estimates

Estimates for construction expenditure are derived from the following base inputs: (1) Manufacturing facility square footage and (2) Construction cost per square foot, which is adjusted based on region, facility size, and use type.

In the absence of direct construction jobs, construction expenditures are estimated for each facility. General factors that impact construction costs include:

- **Location:** Labor and material costs and taxes can differ significantly across the U.S.
- **Facility size:** Larger facilities have lower per square foot construction cost than smaller facilities, all else equal, due to having lower fixed costs per square foot
- **Use type:** Regional distribution warehouses tend to be the least expensive to construct, whereas R&D facilities are the most expensive
- **Building class:** Class A buildings (highest in quality) are more costly than lower quality building classes (Class C/D buildings)
- **Required systems:** Advanced electrical systems, specialized ventilation, or safety features
- **Segment costs:** Site work, base building structure and enclosure, base building architectural, base building mechanical, electrical, and plumbing (MEP), general condition (the cost of managing the project, i.e., administrative and field labor costs) and general requirements (the non-management indirect cost of executing the project, e.g., permitting, inspection, safety and environmental compliance, and project overhead)

Building class, required systems, and segment costs are not explicitly modeled as they are project specific factors.

Given square footage (x), location (l), and use type (u), the construction cost (y) of manufacturing facility (i) takes the following form:

$$y_{l,u} = a_{l,u}*\exp\text{^}(b_{l,u}*x_i)$$

Construction expenditure per square foot is based on data from the following real estate services, analytics, and consulting firms: Cushman and Wakefield's Americas Industrial Construction Cost Guide (2024 edition) and Cumming Group.[98]

Cost of Goods Manufactured Estimates

The cost of goods manufactured (COGM) is generally comprised of the following expense categories at the factory level: direct labor, indirect labor, direct materials, and indirect materials. Direct labor is the cost of wages and salaries for employees directly involved in producing goods or services (e.g., assembly line workers), while indirect labor encompasses the costs of employees in a factory who support the production process but are not directly involved in it (e.g., engineering manager of a production facility). Direct materials are raw materials or components directly used in the production of a finished product, while indirect materials are materials used in the production process that are not directly traceable to a specific product.

The report does not attempt to forecast future COGM domestically for any clean energy components and subcomponents. It is plausible that these costs will decrease as domestic capacity expands and the production process will become more efficient, all else equal, thus requiring lower input costs to maintain the same level of output. For example, manufacturing efficiencies may lead to requiring fewer resources, including labor, to produce the same units of widgets, thus the level of employment supported in the future would be lower than the current level. This may be especially true for relatively nascent technologies such as LFP batteries. For this reason, the economic impacts projected for 2030 may be optimistic relative to the actual future economic impacts.

98 Source: Cushman & Wakefield. Available at: https://cushwake.cld.bz/PDS-Industrial-Cost-Guide-2024; Cumming Group. Available at: https://insights.cumming-group.com/

Clean Energy Supply Chain Details

The primary components and subcomponents that make up clean energy manufacturing mainly comprise of durable goods such as metals, electronic products and fabricated structural products as well as chemical and nonmetallic products such as glass, concrete, and polymers.[99] Compared to nondurable goods manufacturing subsectors such as textiles and food manufacturing, the energy manufacturing processes are considerably more complex and capital intensive, often requiring multiple intricate steps, specialized equipment, and expertise. This intricacy often comes with trade exposure or a series of imports and exports before the final energy component is ready for installation.

While the primary, secondary, and tertiary components for clean energy are different, these components share many of the same raw and processed materials. For example, silica sand (quartz), which is processed into silicone, is a key ingredient in crystalline silicone (c-Si) solar modules, but it is also crucial in glassmaking (for solar panels), printed circuit boards and electrical parts (for solar and battery storage inverters), and anode (for battery storage cells). Only a few raw and processed materials are exclusively for solar (e.g., aluminum oxide) and wind (e.g., balsa). Deploying clean energy projects requires raw and processed materials that range from common construction materials (e.g., concrete) to niche, high-performance materials with limited availability. The clean energy supply chain is rapidly evolving and changing, whether due to technological innovations or geopolitical disruptions, which further complicate an already complex landscape.

Table A9: Existing Clean Energy Manufacturing Facilities Annual Employment Impact, by State

State	Solar
Texas	24,541
Georgia	9,800
Ohio	8,700
Arizona	4,100
Alabama	3,300
Rest of the U.S.	25,000
U.S. Total	**75,400**

State	Wind
Colorado	13,600
North Dakota	5,900
Texas	3,800
Florida	2,300
Oklahoma	2,000
Rest of the U.S.	7,500
U.S. Total	**35,100**

State	Batteries & Energy Storage
California	5,000
West Virginia	2,300
Nevada	800
Utah	600
Hawaii	600
Rest of the U.S.	2,100
U.S. Total	**11,400**

99 Nonmetallic mineral products manufacturing (NAICS 32) and durable goods manufacturing (NAICS 33)

Figure A1: Solar Supply Chain Schematic

Raw Materials	Processed Materials	Secondary Components	Primary Components	Product
Silica sand	Polysilicon	Ingots and Wafers	Cells (c-Si)	Module (c-Si)
Bauxite, steel raw materials	Aluminum alloy, steel		Frames/backrail	
Trona, limestone	Soda ash, lime	Tempered glass	Front glass/back glass	
Crude	Ethylene, vindyl acetate, butene, octene	Ethylene-vinyl acetate (EVA), polyolefin elastomer (PE),	Encapsulant	
		(and maybe PVB, urethane (TPU), ionomer, silicone)		
Crude		Plastic: PVPF, PVF, PET, PE, etc.	Backsheet	
Crude or steel raw materials	Aluminum, stainless steel, plastic	Bushing, Cover	Junction box	
Silica sand	Silicon	Diodes		
	Melamine? Polyamide?	Terminal blocks		
Copper ore	Copper	Wire		
Latex	Rubber	Gasket		
	polyisobutene, polyurethane, silicone, polysulphide	Polyisobutylene butyl rubber, acrylic foam, polyisobutene (PIB), silicone	Edge seals	
Crude, silica sand		EVA, PE, silicone	Pottants	
Crude, silica sand		EVA, acrylate, epoxy, silicone	Adhesives	
Copper ore	Copper	Copper ribbon or flat wire which is coated in solder	Bus ribbons (or tabbing ribbons)	
Silica sand, copper ore, germanium ore	Silicon, germanium, selenium, copper	Semiconductor material (w/ copper wiring)	Bypass diodes	
	Cadmium, tellurium		Cells (Cd-Te)	Module (Cd-Te)
Trona, limestone	Sand, soda ash, limestone		Glass	
			Transparent Conductor	
Cassiterite?	Tin		High Resistivity Conductor	
	Cadmium, tellurium, selenium		Cadmium Selenium Tellurium	
Gold ore, nickel ores (laterites, magmatic sulfide deposits), bauxite	Gold, nickel, aluminum		Metal	
Bauxite	Aluminum		Mounting hardware, Rails, Clamps, Brackets	Racking
Iron ore, coal/coke, limestone	Steel, Concrete		Foundation	

Raw Materials	Processed Materials	Secondary Components	Primary Components	Product
Iron ore, coal/coke, limestone	Steel		Torque tube	Tracker
Iron ore, coal/coke, limestone	Steel		Fasteners, Bearings	
Bauxite, steel raw materials	Aluminum alloy, steel		Frames/backrail	
			Drive Motor	
Silica sand, Gallium, Arsenic, Germanium ore, Indium (byproduct of Zinc mining)	Silicone, Gallium Arsenide, Germanium, Indium	Photodiode, light-dependent resistor, etc.	Sensors	
		Microprocessor	Microcontroller	
		Transistor		
Silica sand	Silicon	Diode		
Silica sand, Gallium, Arsenic, Germanium ore, Indium (byproduct of Zinc mining)	Silicone, Gallium Arsenide, Germanium, Indium	Photodiode, light-dependent resistor, etc.	Control Circuit	
Silica sand	Silicon		Printer circuit board assemblies	Inverter
Crude or steel raw materials	Aluminum, stainless steel, plastic		Enclosure	
Gallium, arsenic	Gallium arsenide	Diode	Electrical parts	
Germanium ore	Germanium	Chip wafer		
Silica sand	Silicon	Silicon Wafer/Ingot		
	Chemicals + Solvent	Photoresist Coating		
Iron ore, coal/coke, limestone, diamond or carbon	Steel, diamond	Diamond Saw		
Indium (Byproduct of Zinc mining)	Indium	Foil		
		Coolant	Climate control	

Figure A2: Land-Based Wind and Offshore Wind Supply Chain Schematic

<table>
<tr><th>Raw Materials</th><th>Processed Materials</th><th>Secondary Components</th><th>Primary Components</th><th>Product</th></tr>
<tr><td>Ire Ore and Copper Ore</td><td>Magnetic Steel and Copper</td><td rowspan="2">Generator</td><td rowspan="18">Nacelle</td><td rowspan="24">Turbine</td></tr>
<tr><td>Neodymium, Praseodymium, Dysprosium, and Terbium</td><td>Rare Earth Oxides (for Permanent Magnet)</td></tr>
<tr><td>Iron Ore</td><td>Cast Steel, Stainless Steel</td><td rowspan="2">Gear Box</td></tr>
<tr><td>Bauxite and Copper Ore</td><td>Aluminum and Copper</td></tr>
<tr><td>Wood and Crude</td><td>Lumber and Plastic</td><td rowspan="2">Yaw Bearing</td></tr>
<tr><td>Carbon</td><td>Carbon Fiber (for Composite)</td></tr>
<tr><td>Iron Ore and Latex</td><td>Steel and Rubber</td><td rowspan="2">Pitch Bearing</td></tr>
<tr><td>Crude</td><td>Thermoplastic Polyurethane</td></tr>
<tr><td>Ire Ore and Bauxite</td><td>Stainless Steel and Aluminum</td><td rowspan="4">Hydraulics</td></tr>
<tr><td>Copper Ore and Cassiterite</td><td>Copper and Tin (for Bronze)</td></tr>
<tr><td></td><td>Chrome</td></tr>
<tr><td>Crude</td><td>Plastic (for Seals)</td></tr>
<tr><td></td><td>Cooling System, Sensors, and Power Converter</td><td>Electrical System</td></tr>
<tr><td></td><td>Platinum Group Metals</td><td>Semiconductors</td></tr>
<tr><td>Sand, Soda Ash, Limestone</td><td>Fiberglass</td><td rowspan="2">Frame</td></tr>
<tr><td>Bauxite</td><td>Aluminum</td></tr>
<tr><td>Iron Ore</td><td>Steel</td><td rowspan="2">Cover</td></tr>
<tr><td>Carbon</td><td>Carbon Fiber (for Composite)</td></tr>
<tr><td>Ire Ore and Bauxite</td><td>Stainless Steel and Aluminum</td><td></td><td rowspan="2">Tower</td></tr>
<tr><td>Sand, Soda Ash, Limestone</td><td>Fiberglass</td><td></td></tr>
<tr><td>Sand, Soda Ash, Limestone Carbon</td><td>Fiberglass and Carbon Fiber (for Composite)</td><td></td><td rowspan="3">Blades</td></tr>
<tr><td>Balsa Wood</td><td>Balsa</td><td></td></tr>
<tr><td>Crude</td><td>Plastic</td><td></td></tr>
<tr><td>Iron Ore</td><td>Steel and Cast Iron (for Large Castings)</td><td></td><td>Hub</td></tr>
<tr><td>Iron Ore</td><td>Steel</td><td>Steel Plate</td><td rowspan="2">Monopile</td><td rowspan="6">Foundation</td></tr>
<tr><td>Iron Ore</td><td>Steel</td><td>S355 Steel</td></tr>
<tr><td>Basalt Stone</td><td>Basalt</td><td>Basalt Rebar</td><td rowspan="4">Jacket</td></tr>
<tr><td>Limestone</td><td>Cement</td><td>Geopolymer Cement Binder</td></tr>
<tr><td>Iron Ore</td><td>Steel</td><td rowspan="3">Suction Anchors</td></tr>
<tr><td>Limestone</td><td>Concrete (Cement)</td></tr>
<tr><td>Gravel, Sand, Water</td><td>Concrete</td><td></td><td rowspan="4">Installation</td></tr>
<tr><td>Iron Ore</td><td>Steel</td><td>Steel Rebar</td><td></td></tr>
<tr><td>Limestone</td><td>Cement</td><td rowspan="2">Concrete</td><td></td></tr>
<tr><td>Gravel, Sand, Water</td><td>Concrete</td><td></td></tr>
</table>

Raw Materials	Processed Materials	Secondary Components	Primary Components	Product
Polymers	Ethylene Propylene Rubber		Insulation	Inter-Array Cables, Subsea Cables
Crude	Polyethylene			
Iron Ore	Steel		Steel Armor	
Crude	Polypropylene		Binding	
Crude	Plastic		Plastic Sheathing	
Copper Ore	Copper		Conductor	
Bauxite	Aluminum			
Iron Ore, Bauxite	Steel, Aluminum		Hull	Vessels
Crude, Sand, Soda Ash, Limestone, Carbon	Plastic, Glass, Carbon Fiber	Fiber-Reinforced Plastic		
Iron Ore	Steel		Anchor	
Iron Ore, Bauxite	Steel, Aluminum		Winch	
Iron Ore, Bauxite	Steel, Aluminum		Cleats	
Adipic Acid and Hexamethylenediamine, Purified Terephthalic Acid (PTA) and Monoethylene Glycol (MEG)	Nylon, Polyester	Synthetic Rope	Mooring Lines	
Iron Ore, Bauxite, Copper Ore	Cast Iron, Steel, Aluminum, Copper		Engine	
See figure for battery storage	Cathode, Anode, Electrolyte, Separator, Foil, Binder	Module/Pack	Battery	
	Semiconductor, Power Circuit	Inverter		
			Electrical Power System	
Carbon	Carbon Fiber	Composite	Trusters	
Iron Ore, Crude, Sand, Soda Ash, Limestone	Stainless Steel, Plastic, Fiberglass			
		Inertial Measurement Units	Navigation	
		Radars		
		Echo Sounders		
		Auto Pilots		
		GPS		
		Automatic Identification Systems	Communication System	
		High Frequency Radios		

Figure A3: Storage Supply Chain Schematic

Raw Materials	Processed Materials	Secondary Components	Primary Components	Product
Nickel ore	Battery Grade Nickel	Cathode Precursor	Cathode	Module/Pack
Manganese ore	Battery Grade Manganese			
Cobalt ore	Battery Grade Cobalt			
Iron ore	Iron			
Phosphate rock	Phosphorus			
Lithium brine, clay, or Spodumene	Lithium Hydroxide, Lithium Carbonate	Lithium		
Natural graphite	Graphite		Anode	
Crude or coal	Synthetic graphite			
Silica sand	Silicon			
Crude	Ethylene	Solvent	Electrolyte	
Lithium brine, clay, or spodumene	Lithium Hydroxide, Lithium Carbonate	Salt (Lithium)		
Fluorspar	Fluorine	Salt (Fluorine)		
Crude	Plastic		Separator	
Copper ore, Bauxite	Copper, Aluminum		Foil	
	N-Methyl-2-pyrrolidone (NMP)	Polyvinylidene (Di)fluoride (PVDF) Resins	Binder	
Silica sand	Silicon		Printer circuit board assemblies	Inverter
Crude or steel raw materials	Aluminum, stainless steel, plastic		Enclosure	
Gallium, arsenic	Gallium arsenide	Diode	Electrical parts	
Germanium ore	Germanium	Chip wafer		
Silica sand	Silicon	Silicon Wafer/Ingot		
	Chemicals + Solvent	Photoresist Coating		
Iron ore, coal/coke, limestone, diamond or carbon	Steel, diamond	Diamond Saw		
Indium (Byproduct of Zinc mining)	Indium	Foil		
Air or water		Coolant	Climate control	

Table A4: Raw and Processed Material Required

Raw and Processed Materials	Wind	Offshore wind	Solar PV (CdTe)	Solar PV (c-Si)
Aggregate	✓			
Aluminum	✓	✓	✓	✓
Aluminum Oxide			✓	✓
Arsenic			✓	✓
Balsa	✓	✓		
Boron	✓	✓	✓	✓
Cadmium			✓	
Cast Iron	✓	✓		
Casting Steel	✓	✓		
Chromium	✓	✓	✓	✓
Chromium Steel	✓	✓	✓	✓
Cobalt	✓	✓	✓	✓
Concrete	✓		✓	✓
Copper	✓	✓	✓	✓
Dysprosium	✓	✓	✓	✓
Electrical Steel	✓	✓		
Epoxy	✓	✓	✓	✓
Gallium	✓	✓	✓	✓
Galvanized Steel	✓	✓		
Glass			✓	✓
Gold			✓	✓
Graphite	✓	✓	✓	✓
Hydrogen Fluoride			✓	✓
Iron	✓	✓	✓	✓
Lithium	✓	✓	✓	✓
Low Carbon Steel	✓	✓	✓	✓
Magnesium			✓	✓
Magnetic Steel	✓			
Manganese	✓	✓	✓	✓
Methyl-3-Methoxypropionate			✓	✓
Neodymium	✓	✓		
Nickel	✓	✓	✓	✓
Niobium	✓	✓	✓	✓
Palladium			✓	✓
Pet Foam	✓	✓		
Plastic	✓	✓	✓	✓
Polyester	✓	✓	✓	✓
Praseodymium	✓	✓	✓	✓
Pvc Foam	✓	✓		
Reinforcing Steel	✓	✓		
Silicone	✓	✓	✓	✓
Silver		✓	✓	✓
Solar Glass			✓	✓
Tellurium			✓	
Terbium	✓	✓	✓	✓
Thermoplastic	✓	✓	✓	✓
Tin	✓	✓	✓	✓
Titanium	✓	✓	✓	✓
Titanium Dioxide			✓	✓
Vanadium	✓	✓	✓	✓
Zeolite			✓	✓
Zinc	✓	✓	✓	✓

While solar PV, wind, and BESS projects require many of the same material inputs, the quantities differ considerably. Figure A42 and Figure A43 summarize the materials required on a per MW basis and based on 2024 deployment levels, respectively. Each clean energy technology requires hundreds of unique material types, here, this analysis groups these materials into the following major categories: (1) Aggregate material, (2) Composites and polymers, (3) Concrete, (4) Glass, (5) Steel, (6) Metals, metalloids, and alloys, and (7) Nonmetals. Common metals, metalloids, and alloys such as aluminum, iron, copper, and zinc among a few others are separated into their own group due to their relatively significant amount of materials required across all technologies.

Figure A5. Materials (in kilograms) required per MW of solar and wind[100]

Consolidated Raw and Processed Materials	Wind	Offshore wind	Solar PV
Aggregate Material (Crushed Stone)	534,920	0	0
Composites and Polymers	9,992	6,125	7,679
Concrete	394,303	0	77,145
Glass	0	0	84,417
Steel	131,609	261,858	108,280
Alumina, Aluminum, Cobalt, Copper, Iron, Nickel, Zinc	17,210	17,873	37,307
Other Metals, Metalloids, and Alloys	3,683	5,448	3,341
Nonmetals	550	1,101	5
Total	**1,092,268**	**292,405**	**318,174**

Figure A6. Materials (in thousand metric tons) required, based on capacity deployed in 2024[100]

Consolidated Raw and Processed Materials	Wind	Offshore wind	Solar PV
Aggregate Material (Crushed Stone)	534,920	0	0
Composites and Polymers	9,992	6,125	7,679
Concrete	394,303	0	77,145
Glass	0	0	84,417
Steel	131,609	261,858	108,280
Alumina, Aluminum, Cobalt, Copper, Iron, Nickel, Zinc	17,210	17,873	37,307
Other Metals, Metalloids, and Alloys	3,683	5,448	3,341
Nonmetals	550	1,101	5
Total	**1,092,268**	**292,405**	**318,174**

100 NREL (updated February 2025). REMPD: Renewable Energy Materials Properties Database. Retrieved from: https://www.nrel.gov/wind/materials-database

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