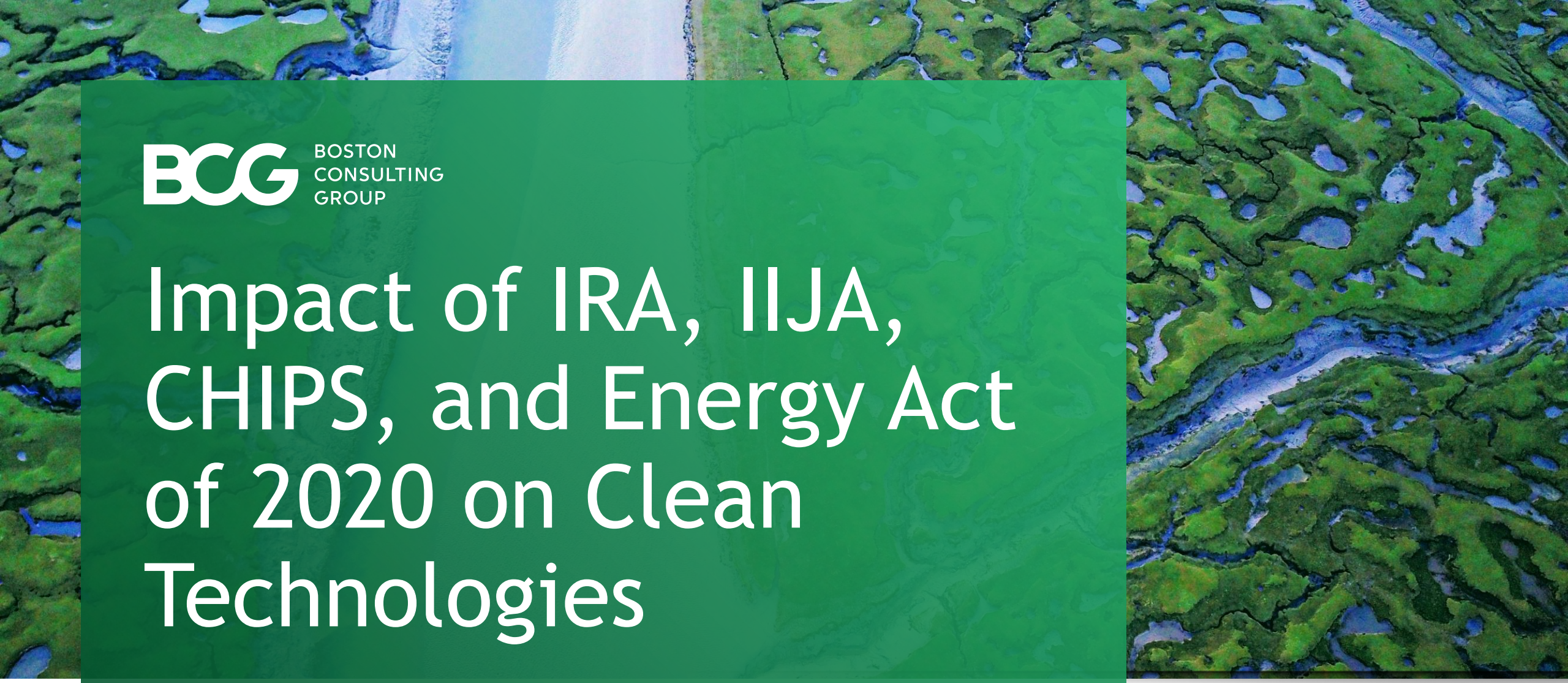

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Impact of IRA, IIJA, CHIPS, and Energy Act of 2020 on Clean Technologies

Deep Dive | Solar PV

APRIL 2023

Background | Objectives and context of this work

Objective

- Explore impacts of recent legislation[1] on U.S. opportunity and remaining challenges for emerging clean technology deployment

Stakeholders involved

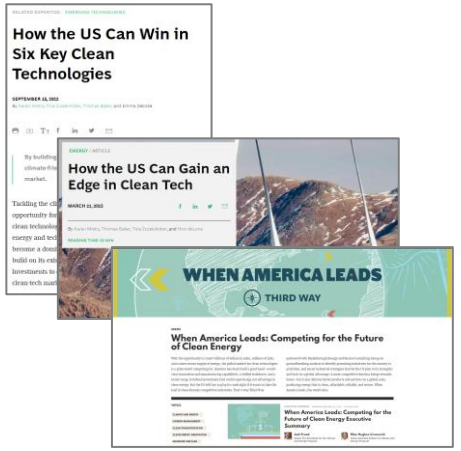
- Analysis was commissioned by Breakthrough Energy and Third Way, with input from stakeholders across the public and private sectors

Breakthrough Energy

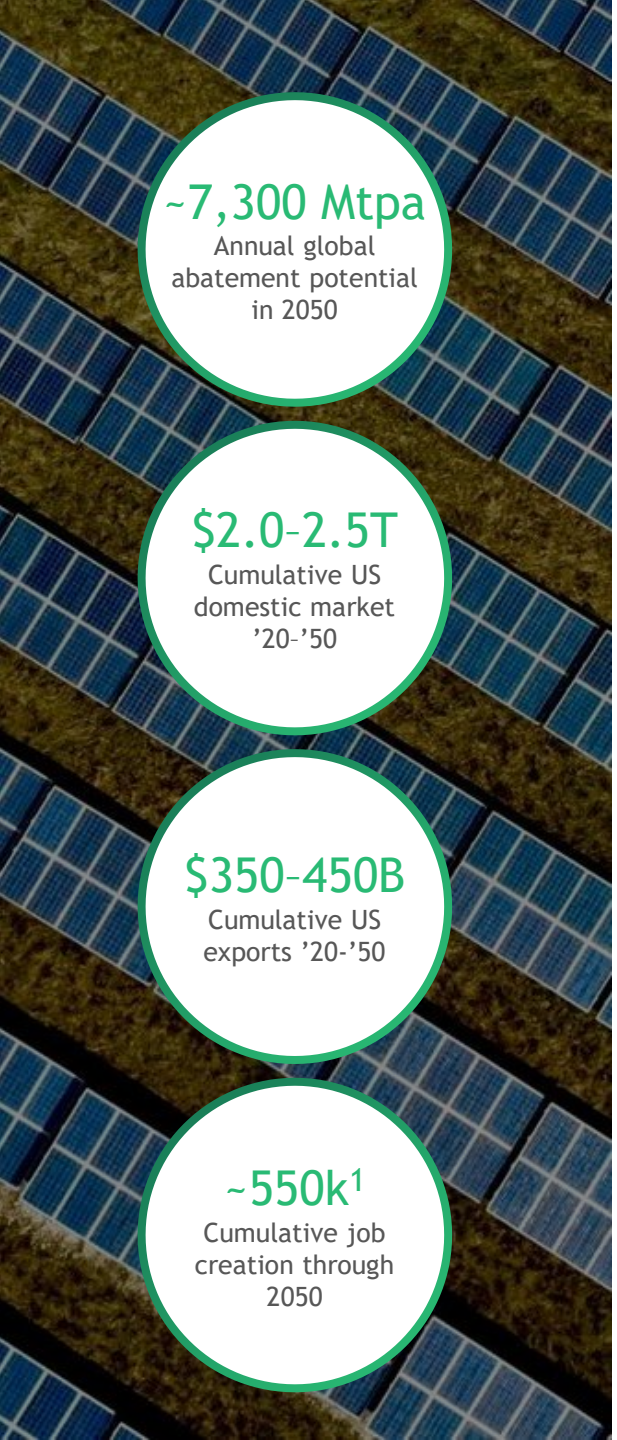
THIRD WAY

Related publications

- BCG report | How the US Can Win in Six Key Clean Technologies
- BCG report | How the US Can Gain an Edge in Clean Tech
- Third Way publication | When America Leads: Competing for the Future of Clean Energy



1. Legislation assessed here includes Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act, CHIPS and Science Act, and the Energy Act of 2020
Source: BCG analysis



Solar PV | Executive summary

- IRA/IIJA provisions provide significant supply and demand-side support to both accelerate domestic solar deployment and incentivize building a domestic US solar supply chain, which is highly concentrated in Asia
- IRA/IIJA provisions are expected to decrease US solar LCOE ~40% and increase US solar capacity deployed 30-40% through 2030 through a mix of domestic manufacturing credits and extended ITC/PTC incentives
- Supply-side incentives are expected to make US-manufactured modules 25-40% cheaper for domestic projects than Asian imports due to manufacturing credits and ITC domestic content adders, driving demand for a US solar manufacturing base; while this may create some export opportunities domestic demand is expected to outstrip domestic supply for the foreseeable future
- However, long-term competitiveness of US manufacturing will depend on US players building vertically integrated manufacturing base and rapidly reducing cost through economies of scale, automation, and product and manufacturing innovations; enabling this will require low-cost financing for manufacturing facilities, workforce development programs, and support for advanced R&D
- Though the IRA/IIJA improve solar project financials, long-standing bottlenecks such as grid expansion, permitting, and interconnection backlogs must be addressed to enable accelerated US solar market growth
- Moving forward, aligning supply-side interests of manufacturers with demand-side interests of developers through guaranteed demand agreements, long-term contracts for developers to build upstream manufacturing capacity, and international partnerships for technology transfer by providing domestic market access is key to fully unlock the potential of the IRA provisions

1. Total number of positions created through 2050; incremental new jobs calculated as the sum of all non-negative one-year differences in # job-years (e.g., 2021 job-years minus 2020 job-years gives 2021 new jobs); incremental new jobs added to sum from prior period for cumulative calculation

Note: Numbers on the left are based on IEA's Announced Pledges (APS) scenario summed up across all value chain segments from 2020-2050

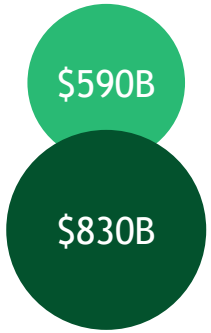
Source: IEA; BCG Analysis

Recent US policies (e.g., IRA, IIJA) have resulted in significant increases in projected size of domestic market, exports, and jobs within solar

US domestic market

US cumulative domestic market ('20-'30) increased from ~$590B to ~$830B after IRA/IIJA due to increased domestic deployments

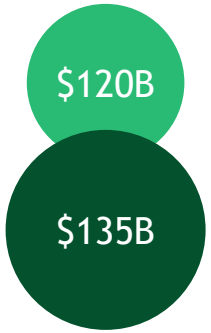
$B in market size



US exports

US cumulative exports ('20-'30) increased from $120B to $135B after IRA/IIJA, a smaller increase as IRA/IIJA mostly affect domestic manufacturing and deployment

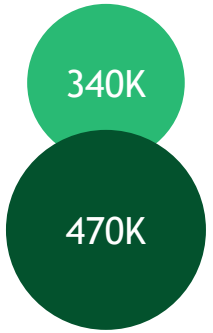
$B in exports



US job creation

New job creation in US solar industry ('20-'30) increased from ~340K to ~470K after IRA/IIJA primarily due to increased domestic manufacturing and deployments

Number of jobs



Note: All numbers based on IEA WEO STEPS scenario pre- and post-IRA based on change over timeframe from 2020-2030
Source: BCG analysis

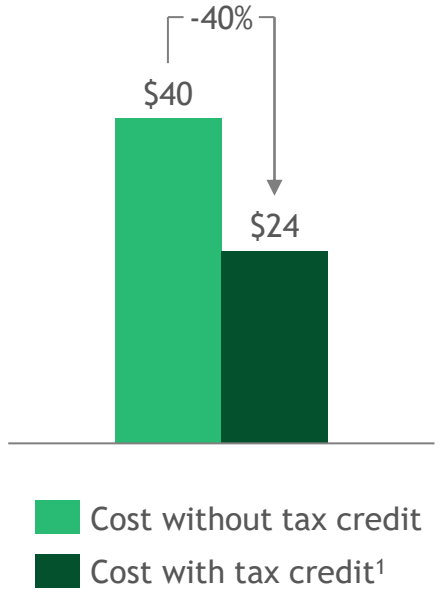
Legislation impacts | IRA and IIJA support of solar expected to reduce levelized cost of energy and increase deployment up to 40% from pre-IRA levels

Demand-side incentives from the IRA include:

1. ITC: **6% base** with 5x multiplier for wage and apprenticeship requirements
2. PTC: **1.5 ¢/kWh** if wage and apprenticeship requirements are met
3. ITC & PTC: **10% bonus** for domestic content + **10% bonus** for plants in energy communities
4. ITC: **Additional 20%** for facilities in qualifying low-income communities

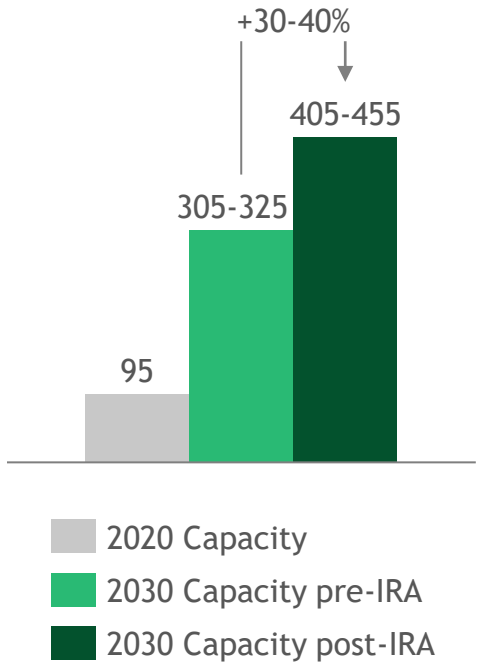
Demand-side incentives decrease LCOE by 40%...

Solar LCOE forecast ($/MWh)



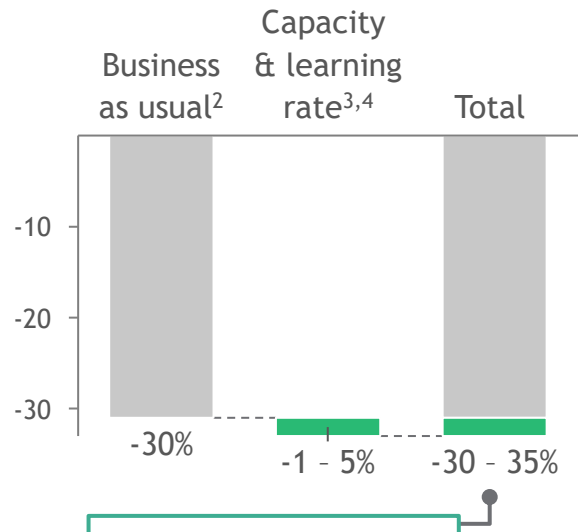
... increasing 2030 capacity 30-40% from pre-IRA levels...

Solar capacity forecast (GW)



...and decreasing unit cost up to ~5% due to added capacity

Incremental % change of unit cost in 2030 relative to 2022



IRA drives an additional ~1-5% cost decline through 2030

1. Assumes 50% Investment tax credit 2. Business as usual: 2030 capacity projection pre-IRA based on IEA stated policy (STEPS) scenario 3. Capacity effect: incremental cost reduction due to added US capacity and additional global deployment (assumed 3x US increase) 4. Learning rate effect: incremental cost reduction due to de-risked commercialization (US moving early) and innovation (improved learning rates)
Note: 2030 cost projection do not account for inflation or subsidies. Source: IEA WEO 2021 and 2022; BCG Analysis

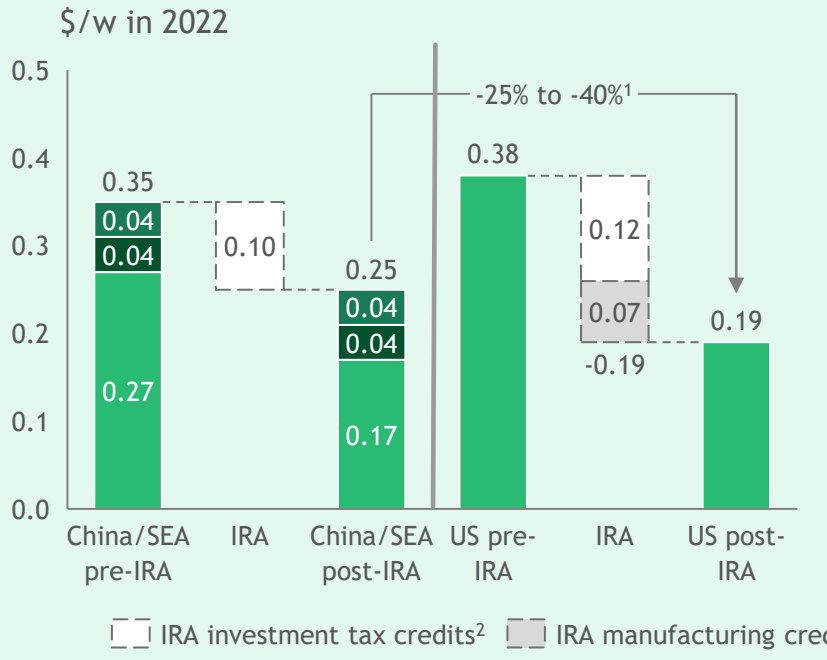
Legislation impacts | IRA provisions for solar are expected to make domestically manufactured modules ~25-40%[1] cheaper than imported modules

IRA's supply-side incentives span the solar value chain

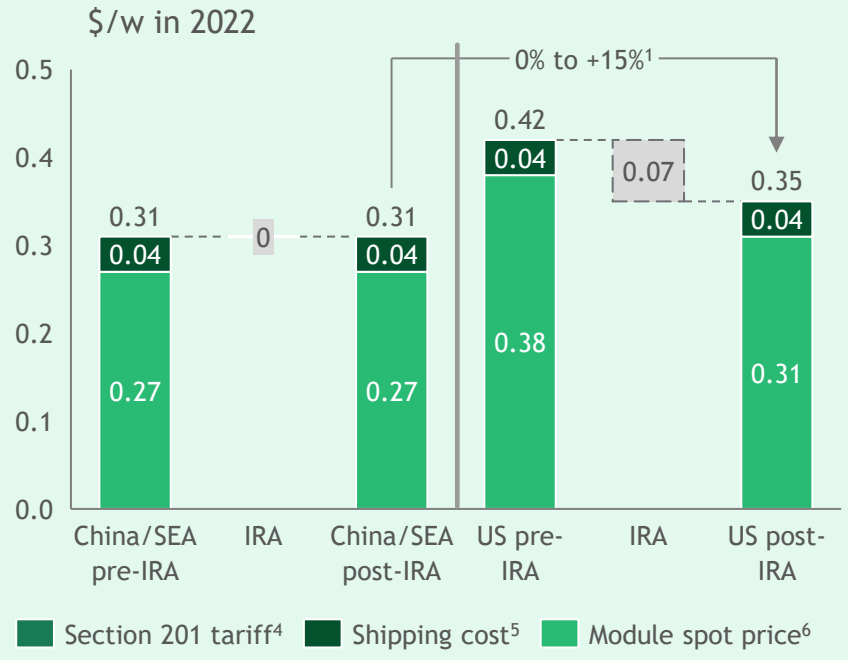
Direction of PV supply chain

- $3/kg for polysilicon
- $12/m² for wafers
- 4 ¢/w for cells
- 0.2 ¢/w for polymeric back sheet
- 7 ¢/w for non-integrated modules

Made in US for domestic market:
US can produce modules domestically for 25-40%[1] less expensive than historical imports



Made in US for exports:
IRA mfg. credits may not make US exports cost competitive with SEA-produced modules

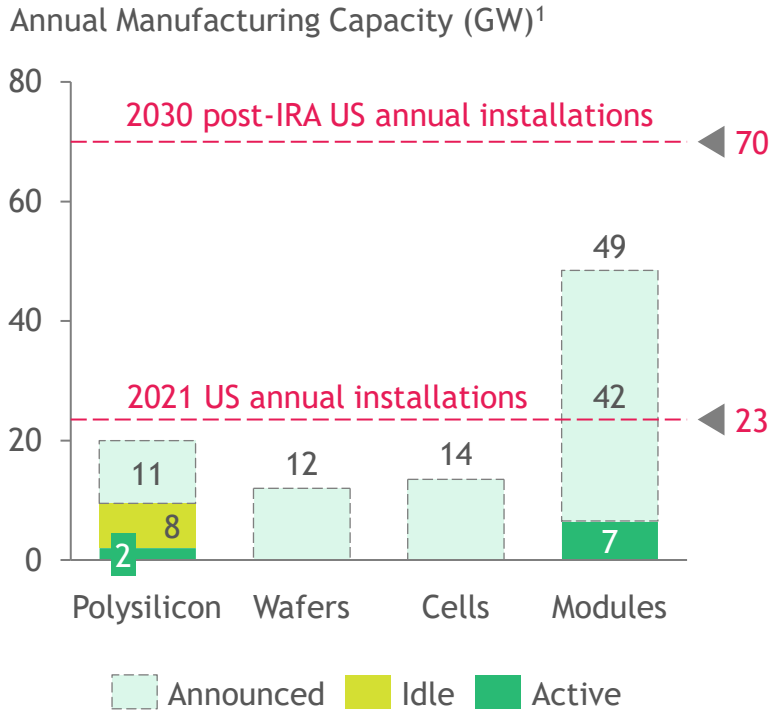


IRA investment tax credits[2] | IRA manufacturing credits[3] | Section 201 tariff[4] | Shipping cost[5] | Module spot price[6]

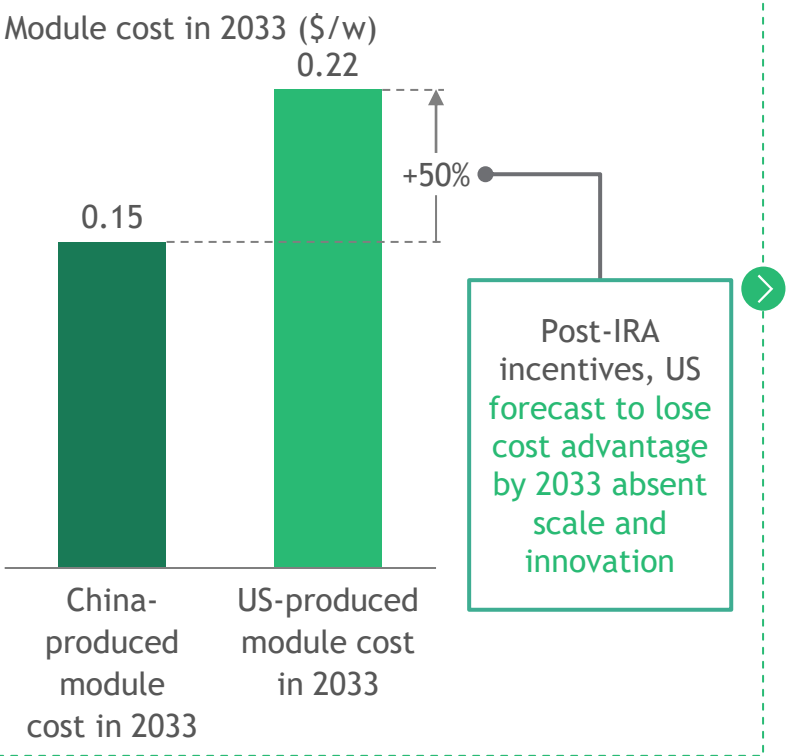
1. Range of cost decline depends on steps produced in the U.S., with favorable end of range assuming all domestic mfg incentives are captured across manufacturing steps and full tax incentives are passed onto the developer; 2. 30%; ITC can range from 6% to 70% – 6% base, 30% if prevailing wages and apprenticeship are met, 10% domestic content bonus, 10% energy community bonus, 20% low-income bonus; 3. Value shown assumes only final assembly in the US; 4. 14.75%; tariffs exempted for 24-months from June 2022 on solar modules imported from Cambodia, Malaysia, Thailand, and Vietnam; 5. Assumption of shipping costs is conservative; 6. Based on historical module spot prices, does not account for forward-looking cost declines; **Note:** The cost advantage due to IRA incentives may not be durable as policies on tariffs shift, logistics costs change, and incentives expire; **Source:** InfoLink, BCG Analysis

Maintaining competitiveness | However, US long-term competitiveness will depend on reducing costs through manufacturing innovation scale

Domestic demand is expected to be 1.5-6x greater than announced supply



Absent scale, US cost advantage will dissipate post-2033



Key avenues to increase cost competitiveness:

- **Rapidly expand domestic capacity** to capture economies of scale
- **Deploy manufacturing automation** to reduce labor costs
- **Integrate supply chains vertically** to increase synergies, lower shipping costs, and reduce reliance on imports
- **Innovate on product and manufacturing** to improve overall efficiency

1. NREL Fall 2022 Solar Industry Update, solar installations are based on IEA's data from the World Energy Outlook 2022 under STEPS for post-IRA capacities.
Source: IRA, DOE Solar PV Supply Chain Review, NREL Fall 2022 Solar Industry Update, SEIA, Credit Suisse, BCG analysis

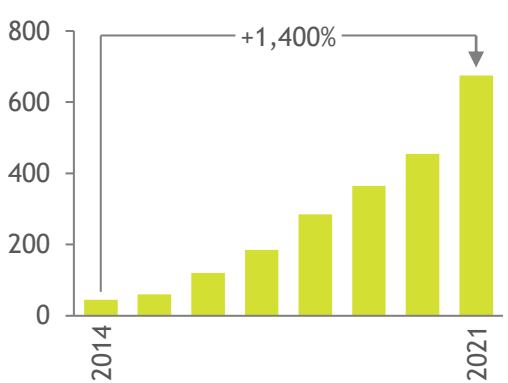
Realizing benefits | Further, interconnection reform, grid expansion, and permitting reform is required to fully unlock demand-side incentives

- Solar interconnection queues in the US have grown faster than other renewables (e.g., ~9x faster than onshore wind)
- Grid expansion and upgrades are needed to ensure grid reliability given increased variability from renewable generation
- Long transmission permitting process hinders infrastructure expansion due to limited clarity around permitting timelines, misaligned interests of stakeholders, and stringent environmental standards

Deep dive into the scale of the transmission challenge for solar in the US

Steady growth in interconnection queues for solar…

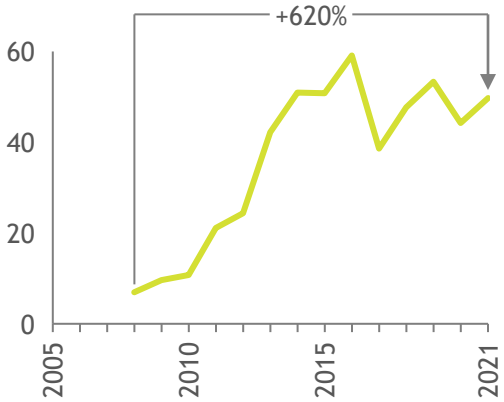
Total Capacity in Queues (GW)



Interconnection queues will continue to increase as requests grow due to IRA incentives

… and processing times of 4+ years from request to operation…

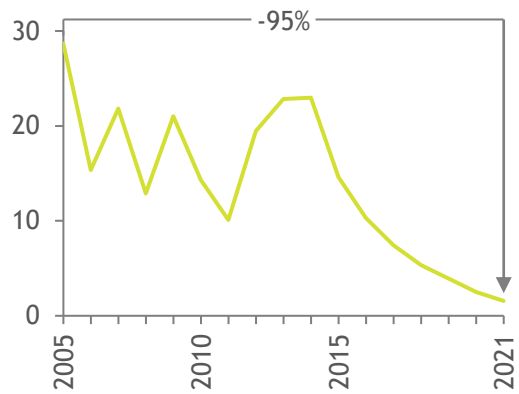
Duration from IR to COD (Months)[1]



Median duration from request to operation has increased from 1 year in 2008 to 4+ years in 2021

… lead to low and steadily decreasing completion rates

Project completion rate (%)[2]

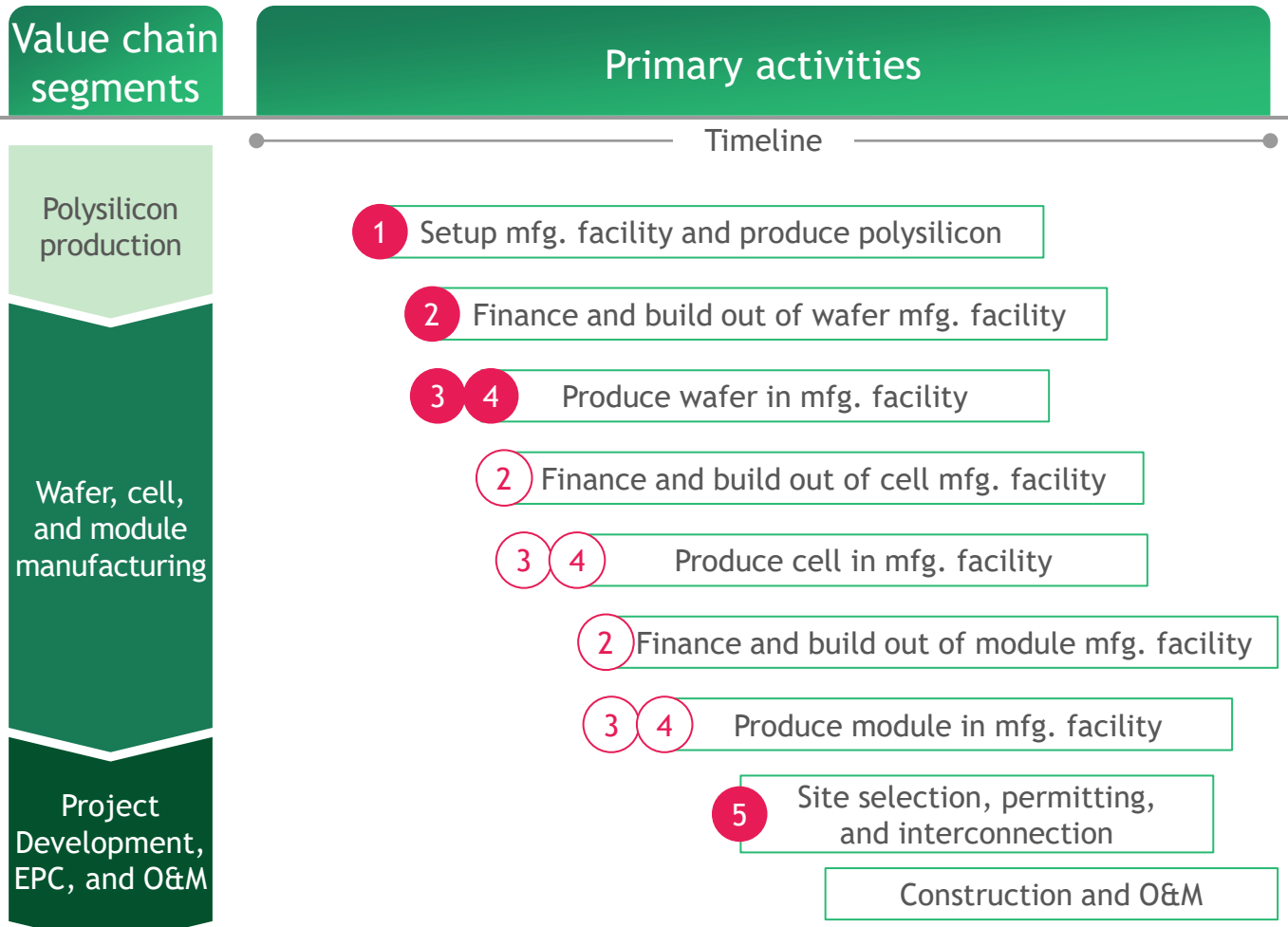


Steadily decreasing completion rates to below 5% inhibit renewable energy growth

1. IR = interconnection request; COD = commercial operation date. 2. Completion percentage includes projects that have been withdrawn for reasons other than transmission bottlenecks.
Source: Lawrence Berkeley National Laboratory (Queued up), IEA WEO 2022, BCG analysis

Pre-legislation challenges | Several areas inhibited domestic solar manufacturing and deployment

Illustrative



Key gaps to be addressed

1. **Uncertainty in demand** for domestic polysilicon and **high production costs**
2. **Bottlenecks in setting up domestic manufacturing base** (e.g., equipment costs)
3. **US operational cost disadvantage** due to high labor and manufacturing costs
4. **Lack of solar-trained skilled workforce** (engineers, scientists) for manufacturing facilities
5. **Long interconnection queues and unclear cost-allocation** for required grid infrastructure upgrades

1. Antidumping and Countervailing Duties 2. Uyghur Forced Labor Prevention Act
Source: BCG Analysis

Remaining challenges | Additional policy is needed to fully unlock legislation benefits and maintain US long-term US competitive advantage

	Pre-legislation priority challenges	Changes from recent legislation (IRA, IIJA, CHIPS, and EA 2020)	Remaining areas to target with future policies
Polysilicon production	1 Uncertainty in demand for domestic polysilicon and high production costs	• 45X advanced manufacturing tax credits for polysilicon ($3/kg) • 48C investment tax credit of up to 30%	• Facilitate polysilicon export to international wafer manufacturers and provide low-cost electricity to domestic polysilicon plants
Wafer, cell, and module manufacturing	2 Bottlenecks in setting up domestic manufacturing base (e.g., equipment costs)	• IIJA $750M Advanced Energy Manufacturing and Recycling Grant Program	☆ Re-assess section 301 tariffs and stringent certifications for PV manufacturing equipment, and provide low-cost land
	3 US operational cost disadvantage due to high labor and manufacturing costs	• 45X advanced manufacturing tax credits for wafer ($12/m^2), cell (4¢/W), and modules (7¢/W) • 48C investment tax credit of up to 30%	☆ De-risk investment to build integrated wafer, cell, and module manufacturing facilities and fund research into manufacturing automation to achieve scale
	4 Lack of solar-trained skilled workforce (engineers, scientists) for manufacturing facilities		☆ Fund and establish solar-focused science and engineering training programs, while maintaining a supportive immigration policy
Project Development, EPC, and O&M	5 Long interconnection queues and unclear cost-allocation for required grid infrastructure upgrades		☆ Reform interconnection processes and enable collaboration between governments, transmission providers, and developers

☆ Priority areas

1. Antidumping and Countervailing Duties 2. Uyghur Forced Labor Prevention Act
Source: IRA; IIJA; DOE; IEA; BCG Analysis

Summary | IRA provides significant support for domestic solar activity, but further action needs to be taken to boost US competitiveness

Key levers that will enable the US to win the solar market

Grid expansion

Additional support for transmission grid development to successfully connect solar to existing grid network

Permitting reform

Permitting reform for transmission infrastructure, manufacturing facilities, and solar projects will enable rapid solar deployment domestically

Interconnection backlog

Support to reduce interconnection timeline and cost to developers will ensure solar deployment is effective and efficient

Workforce development

Funding to setup workforce development programs is essential to ensure availability of skilled labor (scientists, engineers) for upstream manufacturing

Source: BCG Analysis

Backup | New legislation provides incentives for facilities and production of PV Solar (I/III)

	Provision	Summary	Type	Total investment
1	IRA Section 13101: Renewable Energy Production Tax Credit[1]	Extension and modification of PTC for electricity for solar. Base credit of 0.3 cents/kWh and 1.5 cents/kWh if Wage/Apprenticeship requirements are met. Applies to facilities after 2024 and phases down in 2032	Production Tax Credit (PTC)	$51B
2	IRA Section 13102: Energy Investment Tax Credit[1]	Extension and modification of the Investment Tax Credit to expand clean energy manufacturing. 30% ITC and 10% bonus if domestic manufacturing requirements are met. Applies to facilities after 2024 and phases down in 2032	Investment Tax Credit (ITC)	$13.96B
3	IRA Section 13103: Low-Income Solar and Wind Investment Tax Credit[1]	Increase in energy credit for facilities placed in service in connection with low-income communities. 10% bonus for projects located in low-income communities	Investment Tax Credit (ITC)	-
4	IRA Section 13701: Clean Electricity Production Credit[2]	Intended to replace 13101. Tax credit for domestically produced, zero emissions electricity. Facility must be placed into service after December 31st, 2024. Technology agnostic	Production Tax Credit (PTC)	$11.2B
5	IRA Section 13702: Clean Electricity Investment Credit[2]	Intended to replace 13102. Tax credit for domestically produced, zero emissions electricity. Facility must be placed into service after December 31, 2024. Technology agnostic	Investment Tax Credit (ITC)	$50.9B

1. CTVC IRA Tracker 2. RMI 3. Department of Energy FY2023 Budget 4. US Senate
Source: BCG Analysis

Backup | New legislation provides incentives for facilities and production of PV Solar (II/III)

	Provision	Summary	Type	Total investment
6	IRA Section 13302: Residential Clean Electricity Tax Credit[1]	30% residential tax credit for residential solar	Residential	$22B
7	IRA Section 13501: 48C Advanced Energy Manufacturing Project Tax Credit[1]	Extension of the advanced energy project credit. Base rate of 6% and 30% tax credit if wage and apprentice requirements are satisfied	Manufacturing Tax Credit	$10B
8	IRA Section 13502: 45X Wind, Solar, and Battery Manufacturing Production Tax Credit[1]	Advanced Manufacturing Tax Credit, is a credit for manufacturers of eligible components produced within the United States. Tax credits include polysilicon ($3/kg), wafer ($12/m2), cell (4¢/W), and modules (7¢/W)	Manufacturing Tax Credit	$30.6B
9	IIJA Section 40541[2]: Allocation For Public Schools	Grants for energy efficiency improvements and renewable energy improvements at public school facilities	Grant	$500M
10	IIJA Section 40209: Advanced Energy Manufacturing and Recycling Grant Program[2]	Establishes a grant program (FY2022-2026) for facilities that produce or recycle advanced energy technologies (wind, solar, storage, fuel cells, microturbines, geothermal, hydrothermal, and electric grid modernization)	Grant	$750M

1. CTVC IRA Tracker 2. RMI 3. Department of Energy FY2023 Budget 4. US Senate
Source: BCG Analysis

Backup | New legislation provides incentives for facilities and production of PV Solar (III/III)

	Provision	Summary	Type	Total investment
11	IIJA Generally: Relevant solar funding not directly allocated	Unspecific funding for power infrastructure. For other fuels and technology infrastructure	Grant	$14B
12	IIJA Section 40341: Clean Energy Demonstration Program On Current and Former Mine Land[3]	Funding for solar demonstration projects on current and previous mines. Allocated evenly through FY2022-2026	Grant	$500M
13	CHIPS Section 10771[2]	$800M to carry out renewable power research, development, and demonstration activities. $1B for electric grid modernization and security research, development, and demonstration activities	Grant	$1.8B
14	CHIPS Section 10622: Regional Clean Energy Innovation Program[2]	Authorizes a Regional Clean Energy Innovation Program at DOE to establish partnerships that promote the economic development of diverse geographic areas of the US by supporting clean energy innovation	Grant	$250M
15	CHIPS Section 10771: Advanced Research Projects Agency—Energy[2]	Allocates funding to Department of Energy research, development, and demonstration activities (ARPA-E)	Grant	$1.2B

1. CTVC IRA Tracker 2. RMI 3. Department of Energy FY2023 Budget 4. US Senate
Source: BCG Analysis

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