BOSTON CONSULTING GROUP

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

Deep Dive | Clean Steel

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

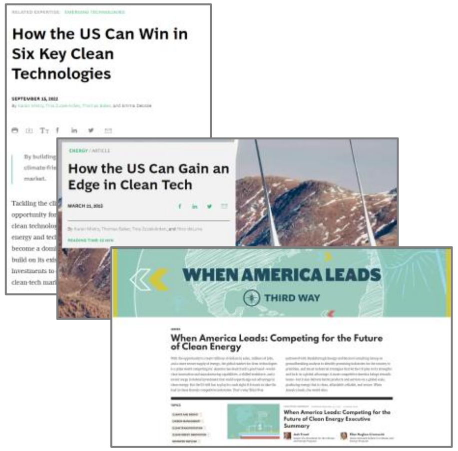
- Analysis was commissioned by Breakthrough Energy and Third Way, with input from stakeholders across the public and private sectors

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

900 Mtpa
Annual global abatement potential in 2050

$0.8-1.0B
Cumulative US domestic market '20-'50

$500-550B
Cumulative US exports '20-'50

~225k[4]
Cumulative job creation through 2050

Clean steel | Executive Summary

- Recent policy provisions provide the US with a path to decarbonize steel, which drives ~7% of global emissions, by reducing the costs of clean steel enablers and making green technology cost competitive with existing technology by 2030

- The US today is already one of the lowest carbon-intensity producers due to ~70% EAF[1] penetration; recent policy further builds on the US advantage by easily decarbonizing EAF[1] production with clean electricity

- Additional incentives for green hydrogen (for use with DRI-EAF[2] plants) and CCUS (for use with traditional BF-BOF[3] plants) provide a path to decarbonize the remainder of US steel production at costs competitive with traditional steel

- While export opportunity is limited by rising protectionism, uncertainty, and US production capacity, the US can lead in domestic uptake, offset clean steel imports, and potentially capture a higher share of the export market if local demand is incentivized

- The US can further build on its leading position by encouraging demand-side incentives to use clean steel, such as through carbon taxes and content requirements, and working with regional trading partners to increase clean steel demand uptake abroad

1. EAF = electric arc furnace 2. DRI-EAF = direct reduced iron, electric arc furnace 3. BF-BOF = blast furnace-basic oxygen furnace 4. Total # 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: All numbers on lefthand side are based on projections from IEA's Announced Pledges (APS) 2021 scenario and are sums across all segments for 2020-2050, except cumulative exports that are summed across prioritized segments (i.e., EPC, OEM, and Offtake)
Source: IEA; DOE; BCG analysis

Current state | The US is currently one of the world's cleanest steel producers given high penetration of EAF production capacity

Steelmaking by Process Route in the U.S.

Process[1]	Scope 1 & 2 emissions[2]	Production by process[3] (2019)
BF-BOF	~1,800 kg CO_2/t CS (most carbon intensive)	30-35 %
NG DRI-EAF	~970 kg CO_2/t CS (much cleaner process)	20-25 %
Scrap-EAF	~370 kg CO_2/t CS (almost clean steel)	40-45%

EAF solutions are much cleaner methods and are easily decarbonized, particularly scrap EAF

Decarbonization Tech Pathways

Decarbonization pathway	Clean steel enablers
BF-BOF → BF-BOF + CCUS Retrofitting existing BF-BOF plants with CCUS	Cheap CCUS Capital investment
BF-BOF → H_2 DRI + green-powered EAF Converting older BF-BOF plants into H_2 powered DRI + EAF facilities	Cheap green H_2 Decarbonized grid Capital investment
NG DRI-EAF → H_2 DRI + green-powered EAF Replacing natural gas with H_2 for iron-making and powering EAFs with green electricity	Cheap green H_2 Decarbonized grid Capital investment
Scrap EAF → Green-powered scrap EAF Using green electricity to fuel scrap EAF plants	Decarbonized grid

Deep dive for each enabler on next page

1. BF-BOF = blast furnace-basic oxygen furnace; DRI-EAF = direct reduced iron, electric arc furnace. 2. Emissions potential is based on EU players but can be approximated for the US 3. Iron & Steel Technology Roadmap 2020 (IEA)
Source: IEA; BCG analysis

Legislation impacts | IRA provisions decrease costs of multiple clean steel enablers, which supports multiple decarbonization pathways

Clean steel enabler	CCUS	Capital investment	Green H_2	Decarbonized grid
Policy provision	IRA: 45Q carbon sequestration credit of \$50-\$85/tCO_2e	IRA: Advanced industrial facilities deployment (\$6B) [1]	IRA: 45V hydrogen production credit of \$3.00/kg H_2	IRA: 60% ITC or \$0.015/kWh PTC for renewable energy[2]
Clean steel industry impact	• CCUS becomes economically viable for BF-BOF given carbon sequestration subsidies	• Advanced facilities deployment program offers pathways to direct funding for building new clean steel plants to replace retiring BF-BOF facilities	• Affordable H_2 makes H_2-DRI pathway cost competitive with NG-DRI pathway by 2030 • Methane fee of \$900-1,500/ton of excess methane speeds up transition from NG to H_2	• Increased investment in clean energy will decarbonize the grid and make EAF production carbon-free • Additionally, green H_2 production will become cheaper
Relevant technologies	• BF-BOF	• BF-BOF • NG DRI-EAF	• BF-BOF • NG DRI-EAF	• NG DRI-EAF • H_2 DRI-EAF • Scrap EAF

1. Grants available for up to 50% of cost of a qualified project and are not specific to clean steel research 2. 30% investment tax credits, plus 10% bonuses for material sourcing and location in energy and low-income (for select technologies) communities

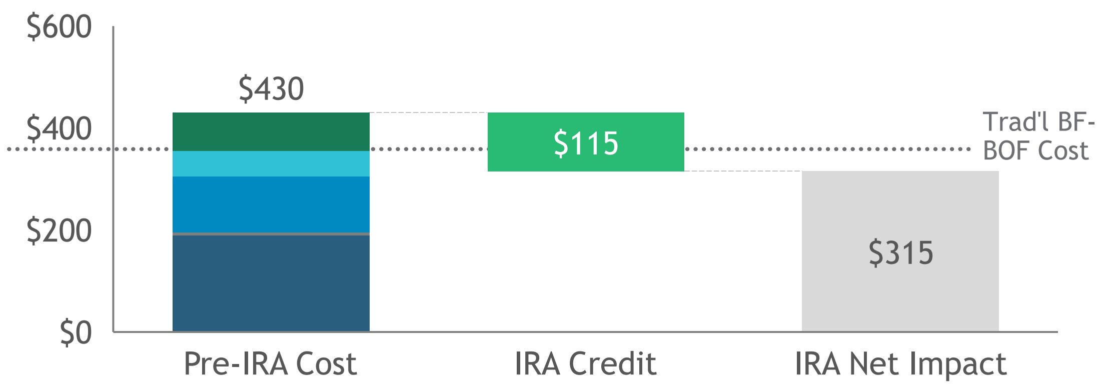
Source: IRA; MPP Steel Sector Transition Strategy; EIA; BCG Analysis

Legislation impacts | IRA CCUS and green hydrogen incentives are expected to make clean steel cost competitive with traditional steel by 2030

BF-BOF: Retrofitting plants with CCUS[2]

45Q carbon sequestration credit: \$50-85/t CO_2e

US levelized cost of steel production in 2030, \$/tcs1

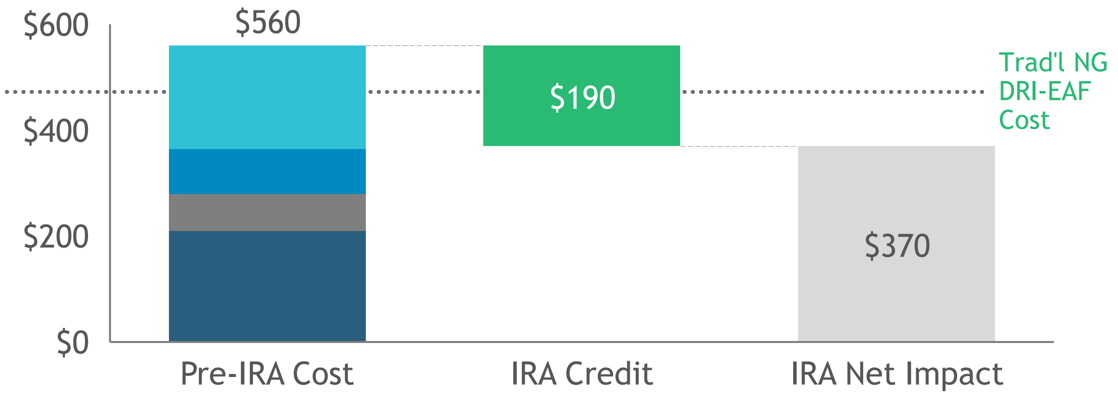


- CCUS costs are predicted to be ~\$50/tCO2e in 2030, which is offset by the maximum value of the 45Q credit of \$85/tCO_2e
- Post-IRA costs are less than BF-BOF costs at \$360/t CS

DRI-EAF: Using green H2 as fuel[3]

45V green hydrogen production credit: \$3/kg H_2

US levelized cost of steel production in 2030, \$/tcs1



- Expected cost for green hydrogen in 2030 of \$2.5/kg of H_2 is lower than the 45V credit of \$3/kg of H_2
- This brings post-IRA costs below traditional NG DRI-EAF costs at \$450/t CS

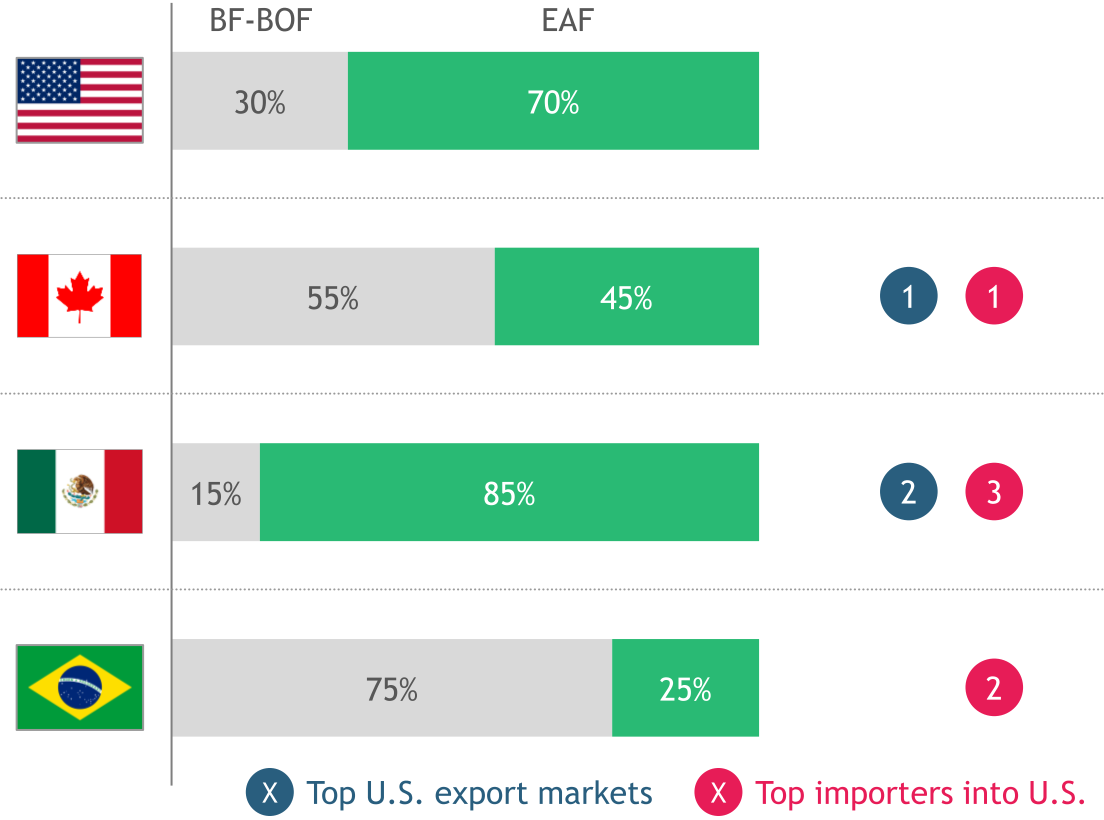
CCS Cost | Fuel | Other Opex | Capex | Raw Material

1. Cost estimates modeled on expected prices in the US, and may vary based on locations, geospatial factors, industrial clusters for CO2 utilization, and access to hydrogen. All scenarios assume captive green electricity to power hydrogen production or carbon capture and continuation of IRA tax credits for life of facility. 2. Remaining CO2 is 0.5 t CO2/t CS. 3. Assumes hydrogen produced onsite. Remaining CO2 is 0.1 t CO2/t CS. Note: Numbers are rounded and for informational purposes only. These projections do not constitute any form of price guarantee

Source: GCCSI 2021 Technology Readiness and Costs for CSS; IEA; BCG Analysis

Demand | The U.S. can offset imports of non-clean steel and increase exports if local markets incentivize clean steel through demand-side policies

Steel production by type[1]



Import and export implications

- U.S. is well-positioned to recapture imports from countries with high BF-BOF penetration, if the government imposes demand-side border tariffs for dirty steel
- U.S. 2050 net zero goal likely creates future clean steel demand, but falls short of notably affecting clean steel uptake now

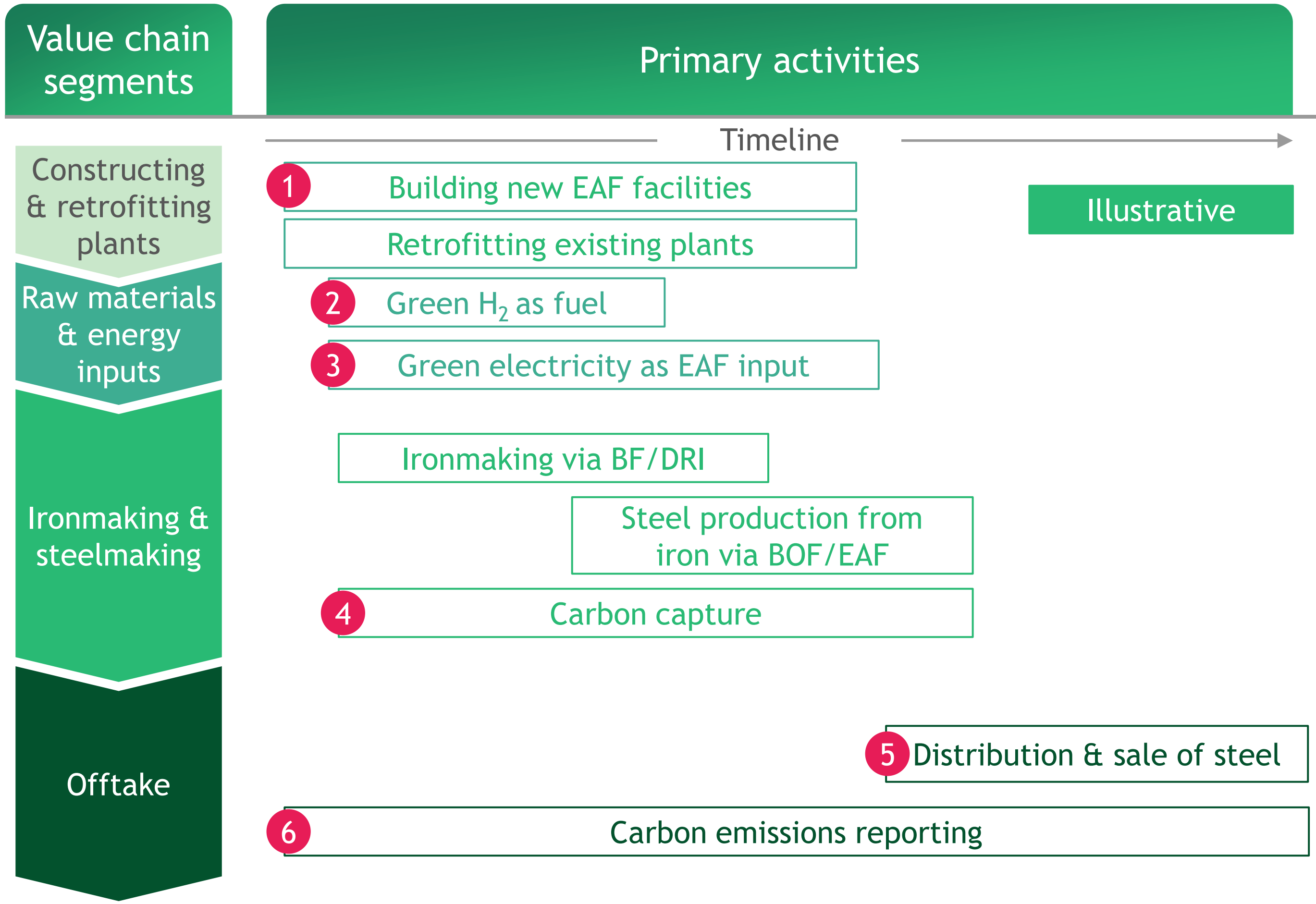
- Canada's programs penalizing high-emitting steel companies and 2050 net-zero aspirations will likely increase future demand for clean steel
- U.S. can possibly capture higher share of export market since it can produce clean steel more cheaply due to higher EAF penetration

- Shifting export profile to Mexico depends on Mexico introducing demand-side policies to incentivize clean steel use

- Brazil has a high reliance on carbon-intensive BF-BOF production
- While Brazil is not a large export market, U.S. could increase clean steel exports if Brazil introduces policies that support a shift to clean steel

1. From World Steel in Figures 2021 (World Steel Association)
Source: IIJA; IEA; BCG Analysis; Global Steel Trade Monitor; World Steel Association (World Steel in Figures 2021)

Pre-legislation challenges | Decarbonizing the steel industry faced several key gaps, such as increasing demand and commercializing technologies



Key pre-IRA gaps to be addressed

1. Pilot clean steel plants have high investment needs
2. Green hydrogen, which remains costly, has yet to be fully commercialized
3. Full decarbonization of U.S. electric grid unlikely until distant future
4. Carbon capture puts a cost and regulatory burden on steelmakers
5. Need for targeted demand-side policies that increase offtake of clean steel
6. No standardized mechanism to measure steel production emissions intensity

Source: IRA, IIJA, DOE, IEA, BCG Analysis

Remaining challenges | Legislation indirectly addresses some priority issues for clean steel, but additional policy is necessary to achieve full decarbonization

	Pre-legislation priority challenges	Changes from recent legislation (IRA, IIJA, CHIPS, and EA 2020)	FUTURE Remaining areas to target with future policies
Constructing & retrofitting plants	1 High investment needs (~$1B per mill) for pilot plants	• ~$6B for advanced facilities deployment program	• Further financial support and long-term monetization opportunities required in a capital constrained industry
Raw materials & energy inputs	2 Green H_2 currently very costly produce, constrained by limited renewable electricity and immature market	• 45V clean hydrogen production credit • ~$8B for development of clean H_2 hubs	☆ H_2 costs remain high and **innovation within efficiency improvements** and fuel consumption reduction is needed
	3 U.S. electric grid unlikely to be decarbonized until 2035 and beyond	• ITC and PTC for clean energy production • RD&D support of clean technologies	• Renewable energy deployments must be significantly accelerated to decarbonize with unresolved concerns around reliability
Ironmaking & steelmaking	4 Breakthrough technology still in early pilot stage and very costly	• Expanded $60-85/tCO2e tax credit from 45Q in IRA and funding into RD&D • SUPER Act and CIT[1] Act	☆ **Remaining challenges** around **deploying CCUS at scale,** including insufficient infrastructure and high cost of CCUS applications
Offtake	5 No targeted demand-side incentives for steelmakers to decarbonize production		☆ **Limited demand for clean steel** without demand-side policy support to incentivize clean steel offtake
	6 No consistent process to certify steel production emissions intensity		☆ Need for public, **regulated carbon-tracking mechanism** to monitor carbon intensity across steelmakers

☆ Priority areas

1. CIT = Clean Industrial Technology Act. Both SUPER and CIT Act requires the DOE to establish RD&D programs for development and commercialization of industrial emissions reduction technologies. Source: IRA, IIJA, DOE, IEA, BCG Analysis

Summary | Actions to further boost US competitiveness

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

Innovation in clean steel refining

Ongoing innovation to drive efficiency improvements and reduce fuel consumption & waste in all stages of the production process

Commercialization of CCUS

Support for early commercial deployments, permanent monetization opportunities beyond 2032, and clearer permitting processes to accelerate CCUS deployment

Demand-side policies

Carbon taxes and tariffs, financial subsidies, and content requirements to provide demand baseline and incentivize clean steel offtake

Public carbon tracking

Standardized, public emissions accounting for both domestic and foreign steel producers to measure carbon intensity

Source: BCG Analysis

Backup | New legislation provides incentives to decarbonize the grid, which helps produce Clean Steel (I/II)

Provision	Summary	Type	Total investment
1 IRA Section 13101: Renewable Energy Production Tax Credit[1]	Extension and modification of PTC for electricity for wind. Base credit of 0.3 cents/kWh and 1.5 cents/kWh if Wage/Apprenticeship requirements are met. Ends for facilities after 2024 and is replaced by 13701	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. Ends for facilities after 2024 and is replaced by 13702	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, only for facilities under 5MW. 10% bonus for project located in low-income communities	Investment Tax Credit (ITC)	Uncapped
4 IRA Section 13701: Clean Electricity Production Credit[2]	Intended to replace 13101 and phases out in 2032. 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 and phases out in 2032. Tax credit for domestically produced, zero emissions electricity. Facility must be placed into service after December 31st , 2024. Technology agnostic	Investment Tax Credit (ITC)	$50.9B

1. CTVC IRA Tracker. 2. BakerHostetler
Source: BCG analysis

Backup | New legislation provides incentives for additional clean steel enablers (II/II)

	Provision	Summary	Type	Total investment
6	IRA Section 13204: Clean Hydrogen	New 45V clean H_2 production credit paid for all production over the first 10 years. Full value is $3/kg adjusted based on life cycle GHG emissions	Production Tax Credit (PTC)	$13.1 billion to 2032
7	IRA Section 13104: CCUS	Increases tax credit 45Q for sequestration and utilization to a maximum of $180/t for sequestration and $130/t for use with additional prevailing wage and apprenticeship requirements	Production Tax Credit (PTC)	$3.22 billion to 2033
8	IRA Section 60113: Oil & gas methane fee	Creates a few of $900-1,500/ton of excess methane and increases costs for oil and gas producers	Fee	Not applicable
9	IRA Section 50161: Advanced industrial facilities deployment	Offers pathways to direct funding for capital expenditures for decarbonization for grants of up to 50% of cost of a qualified project	Grant Funding	$6 billion
10	CHIPS 10751: Low-emissions steel manufacturing research program	Authorizes DOE RD&D and commercial application program of advanced tools, technologies, and methods for low-emissions steel manufacturing across key technology areas1 and support collaborations between with industry, higher education institutions, and the National Laboratories	NA	No funding named
11	Energy Act: SUPER Act of 2021	Requires the DOE to establish an RD&D and commercialization program of advanced technologies and methods for low-emissions steel mfg.	NA	No funding named
12	Energy Act: Clean Industrial Technology Act of 2019	Requires the DOE to establish an RD&D program to further development of industrial emissions reduction technologies through grants and funding	NA	No funding named

To be eligible for IIJA funding, federal agencies are required to ensure that any federally funded infrastructure projects use U.S.-made iron, steel, manufactured products and construction materials

Source: DOE; IRA; IIJA; BCG Analysis

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