Great Lakes Near-Zero-Emissions Steel

Memo Focus: Ohio

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Ohio overview

Ohio is the second largest steel producer in the Great Lakes, accounting for roughly 12% of US raw steel production in 2022. The state is home to two BF-BOFs in Middletown and Cleveland, nine EAFs distributed across the northern third of the state, and a DRI plant in Toledo. Both BF-BOF facilities have an annual crude steel production capacity of 3 million tons and have received reline investments recently. Hence, they will not be due for additional capital investment until early next decade. The Middletown facility produces coke on-site for use in blast furnaces, while the Cleveland facility receives coke from external facilities, likely Haverhill (SunCoke) and Warren (Cleveland-Cliffs). Cleveland-Cliffs' Toledo DRI plant came online in 2020 and is the sole producer of hot briquetted iron (HBI) in the Great Lakes and one of the only three DRI facilities in the United States.[1] The site uses natural gas to reduce DR-

Figure 1: Ohio steel and related assets

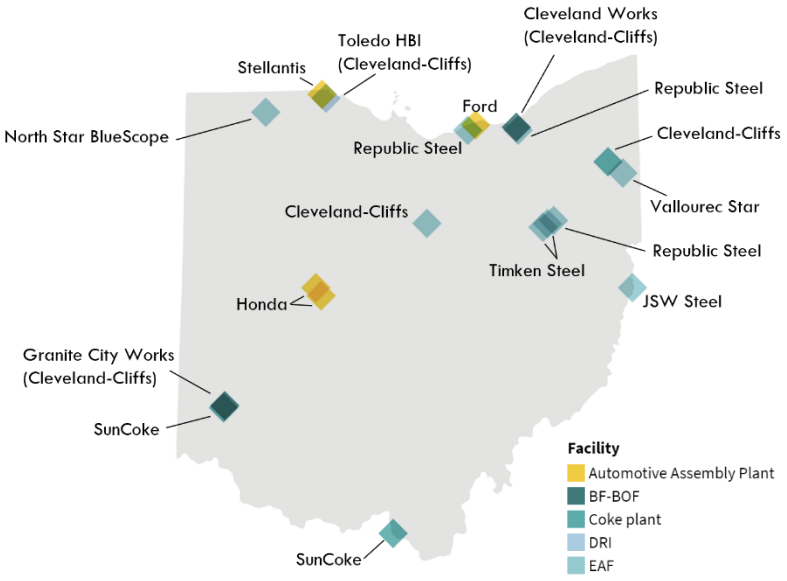


Table 1: Steel supply chain production capacity

Product	Type	State production capacity (million tons)	Great Lakes production capacity (million tons)
Raw material	Iron ore pellets**	0	41
Raw material	Coke	2.2	11.6
Intermediate material	Direct reduced iron (DRI)	1.9	1.9
Steel (recycled)	Electric arc furnace (EAF)	9.6	28
Steel	Blast furnace-basic oxygen furnace (BF-BOF)	6*	36

**Includes currently idled Granite City Works.*

*** State and Great Lakes production capacity reflect production volumes for 2022.*

[1] HBI is a lower-carbon (compared with pig iron produced in blast furnace) iron feedstock produced at DRI facilities and can be used in BOFs and EAFs for steel production. The other 2 DRI facilities are in Louisiana and Texas operated by Nucor and ArcelorMittal respectively.

grade iron ore pellets sourced from Minnesota. Ohio and Indiana are the only states in the Great Lakes that lack a legislatively supported climate action plan, although one is expected to be in development following the funding awarded to Ohio and its four largest metropolitan areas (Dayton, Cleveland, Cincinnati, and Columbus) through the Climate Pollution Reduction Grant Program in the spring of 2023.

Current issues and impact

In the spring of 2023, Cleveland-Cliffs completed hydrogen injection trials at its Middletown plant. The trials were deemed successful and Cliffs is now pursuing commercial production using this method at its Indiana Harbor facility. While this process does reduce coke demand in the blast furnace, the emissions abatement potential is limited to roughly 21%.[2] Coke and steel production facilities, largely due to their reliance on coal, are responsible for considerable emissions of hazardous and criteria air pollutants. After over a decade of Clean Air Act violations at its Cleveland facility, ArcelorMittal (former owner) paid upward of $370,000 in settlement to the state of Ohio in 2020, as part of a larger $5 million settlement stemming from violations across Indiana and Ohio. Ohio and Wisconsin are the only two Great Lakes states to have positive trends across the steel market indicators depicted in Figure 2. These trends signal the strength of Ohio's downstream steel market to potential investors and developers. Ohio, tied with Minnesota, posted the largest growth in GDP of all states in the region from 2010 through 2022. Employment in the state's steel production has fluctuated over the last decade with the closure of the RG Steel mill in Warren in 2012 and opening of the Toledo DRI in 2020.

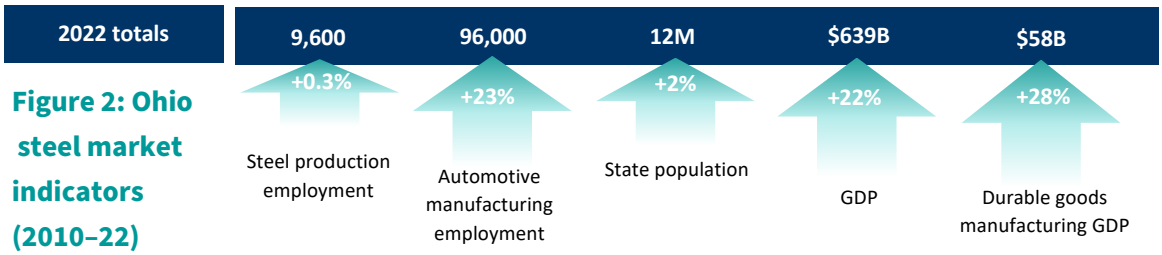


Figure 2: Ohio steel market indicators (2010–22)

Note: GDP metrics are measured in 2012 chained dollars

Data source: Bureau of Economic Analysis, United States Census Bureau. United States Regional Economic Analysis Project

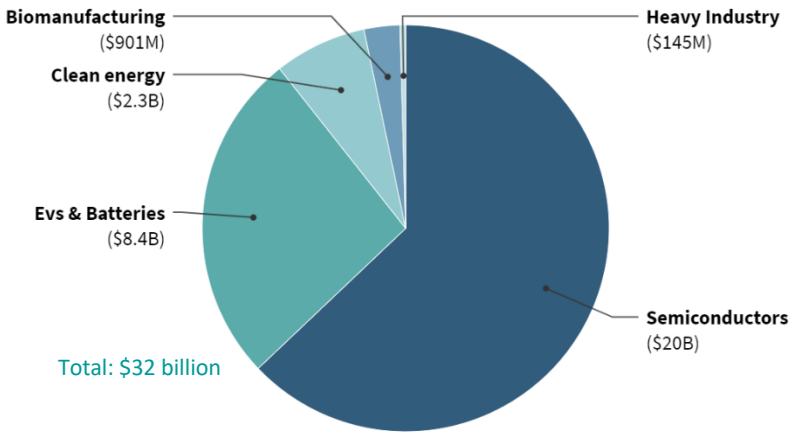
The automotive market accounts for approximately 25% of the US steel demand. Automakers drive the domestic demand for low-emissions steel products, accounting for 56% (or 3.2Mt) of the projected low-emissions steel demand by 2030. Most of that demand is for ore-based steel products, which cannot currently be made using high scrap content steel, typical of EAF facilities. This specific demand segment necessitates the production of near-zero-emissions intermediate iron products such as HBI made using hydrogen or carbon capture and sequestration (CCS) technologies. Ohio has long been a leader in the US auto supply chain and is well-positioned to take advantage of the automotive sector's growing appetite for low-emissions

[2] Emissions abatement potential refers to the potential percentage of greenhouse gas emissions eliminated by switching to the new production method. For the hydrogen blast furnace blending case, the 21% abatement potential assumes hydrogen is produced without upstream emissions.

steel. As Figure 3 indicates, Ohio secured private automotive manufacturing investment of roughly $8.4 billion since the passing of the Inflation Reduction Act (IRA) in 2022. Neighboring states such as Michigan and Indiana also recorded substantial automotive investments in the same period ($19.5 billion and $7.8 billion, respectively). Automotive manufacturers are likely to remain a long-term, reliable off-take segment for low-emissions steel in the region.

Recent growth in solar manufacturing in Northwest Ohio signals additional offtake appetite. In Pataskala, Invenergy and Longi are jointly developing the largest US solar manufacturing facility (5GW) in the United States; it is expected to become operational by the end of 2024. First Solar, the largest US solar manufacturer based in Ohio, is expanding its 3.6GW Perrysburg factory near Toledo. Developers in the clean energy sector have started to signal demand for low-emissions steel products via several methods and are expected to be responsible for nearly 10% of the low-emissions steel demand by 2030. Given the magnitude of local and regional demand in the clean energy and automotive manufacturing sectors, investments in near-zero-emissions steel in Ohio would be well positioned.

Figure 3: Post-IRA clean manufacturing investments in Ohio



Data source: Climate Power, US White House.
Note: data sources leverage information form public announcements, investment totals may not be comprehensive

Steel development opportunities in Ohio

Cleveland-Cliffs' HBI plant is one of the largest industrial development projects to break ground in the Great Lakes in the last decade and has resulted in a surge in economic activity in East Toledo, providing nearly 2,000 construction jobs, over 130 permanent jobs, and additional public infrastructure investment in neighboring ports, railways, and roads. The Toledo site was formerly home to a Chevron refinery. In addition to the incumbent refinery infrastructure the local port authority made a $28 million investment to improve rail, port and energy infrastructure. The facility can become the first near-zero-emissions HBI facility in the country by replacing natural gas with renewably produced hydrogen.

Table 2: Potential near-zero-emissions steel production pathways in Ohio

Production pathway (2 mt/year)	Investment capital ($billion)		Emissions reduction potential		Projected Timeline (years)
	H_2	CCS	H_2	CCS	
CCS development at either BF-BOF facility	N/A	1.3	N/A	46–59%*	2
BF-BOF → DRI-EAF asset conversion	1.2	1.7	68–86%	57–79%	3+
DRI-EAF (inc of new casting & rolling)	1.8	2.3	68–86%	57–79%	3+

Note: Emissions reduction potential relative to unabated BF-BOF steel production. Emissions reduction potential based on scope 1, 2, and 3 emissions for hot rolled coil production. Range is a product of varying scope 2 emissions from US grid average (0.37 tCO2/MWh) to dedicated renewable energy, varying pellet-making fuel from natural gas to pyrolysis oil and varying natural gas methane leakage rate from 1.2% to 2.5%. Assumed capture rate for all CCS technology is 90%, conservative value yet to be proven at scale. Capital for hydrogen production pathways do not include upstream renewable energy or hydrogen assets. Classification as near-zero-emissions production is dependent on actual system configuration and realized emissions abatement.

** BF-BOF with CCS range reflects the option of applying capture technology to upstream coke facilities.*

In addition to reducing emissions from the Toledo DRI facility, several large-scale investments (listed in Table 2) can help advance the near-zero-emissions steel production market in Ohio. Brownfield DRI construction on Cleveland-Cliffs' BF-BOF footprints may be the most attractive option for investors and developers. Both the Cleveland and Middletown sites have access to preexisting transport infrastructure (dock, rail, heavy haul roads) for construction and operation logistics, available natural gas, water, electrical power, and a highly skilled local industrial workforce.

Although both of Cleveland-Cliff's BF-BOF facilities are not due for reline investments in the immediate future, capturing the time-sensitive federal subsidies included in the IRA for carbon sequestration (45Q) and hydrogen production (45V) makes immediate technology transitions financially attractive for steel producers. Converting Cleveland-Cliffs BF-BOFs to hydrogen-based DRI-EAF production has the greatest potential to cost-effectively reduce greenhouse gas emissions and local pollution from steelmaking operations in the state. Achieving the greatest possible emissions reduction is not only essential from the climate perspective but also crucial for steel producers seeking to capitalize on the green premiums developing in the market.

CCS is a feasible yet limited option to reduce emissions at the BF-BOF facilities. BF-BOF CCS abatement potential is limited to approximately 60%, but the infrastructural complexities of retrofitting CCS technology onto all the individual point sources at these facilities may bring this percentage down considerably. For all CCS pathways, whether at a BF-BOF or new DRI facility, capture rates must be maintained at high levels (90% or greater) and upstream methane leakage from fossil sites (coal mines and natural gas wells) must be accounted for and certified. CCS projects will also require close monitoring and regulation of subsurface storage and pipeline infrastructure to mitigate leaks and malfunctions. To date, no BF-BOF facility globally operates commercial scale CCS systems.

Developing hydrogen and CCS infrastructure

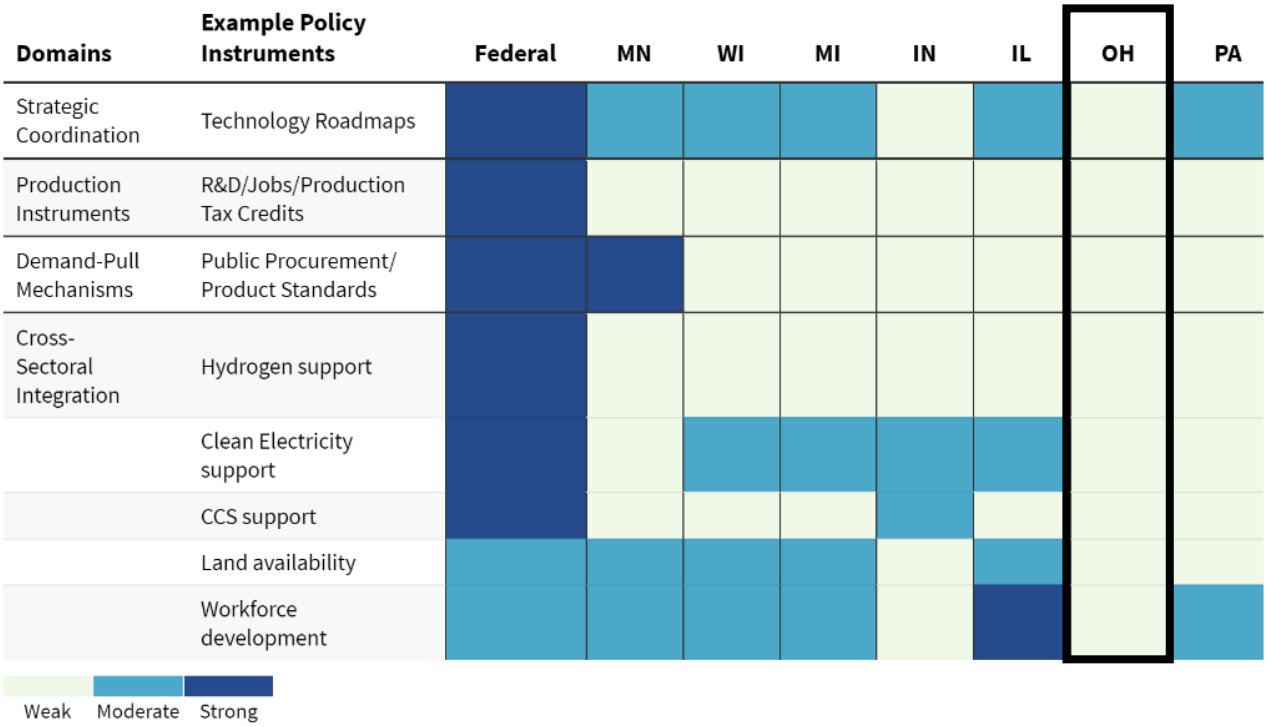
In October 2023, the Appalachian Hydrogen Hub (ARCH2), formed by Ohio, West Virginia, and Pennsylvania, was one of the seven hydrogen hubs across the United States selected to receive up to $925 million in funding from the DOE's $7 billion Regional Clean Hydrogen Hubs (H2Hubs) Program. The ARCH2 hub intends to produce mostly fossil derived hydrogen using natural gas and carbon capture systems. The majority of the hub development projects project to take place in West Virginia with some crossover into Northeastern Ohio and Southwestern Pennsylvania. Steel is not explicitly prioritized as an off-take sector for ARCH2-supported hydrogen production but there will be opportunities for steel producers to expand on the developing infrastructure.

Although legislative state support has not yet materialized, Ohio has demonstrated CCUS leadership over the last 20 years. As an influential member of the Midwest Regional Carbon Sequestration Partnership (2003–20) and Midwest Region Carbon Initiative (2020–current), Ohio has long committed research funding toward geologic site characterization and small-scale CO_2 injection tests to demonstrate geologic storage potential in the Ohio River Valley and adjacent areas. Ohio is the only state in the Great Lakes seeking state primacy over CO_2 sequestration wells, which would allow the state's regulatory agencies to handle permit applications and potentially shrink the development timelines of CO_2 injection wells.

Supporting policy

Policy and investor support for the CCS and hydrogen industries will be critical for each of these pathways. However, Ohio currently provides the least amount of legislative support for near-zero-emissions steel production of any of the Great Lakes states. As Figure 4 indicates, Ohio does not provide policy support in any of the critical segments identified for near-zero-emissions steel development. In fact, legislation passed recently has hindered progress, particularly in the clean energy arena. Grid decarbonization will be essential to facilitate clean electrolytic hydrogen production for those not pursuing behind-the-meter options and for supplying low-emissions power to the state's EAF fleet. In recent years, the Ohio energy landscape has been dramatically impacted by HB6, a 2020 house bill that reduced renewable portfolio standards and subsidized nuclear and coal power production. Although segments of this bill were repealed, rate payer dollars remain subsidizing coal power production in the state. Additionally, SB52, passed in 2021, helped county-level officials block wind and solar development in their respective communities. This bill directly contrasts legislations such as that passed in New York, which focuses on centralizing permitting processes for renewable projects. The centralized permitting process has helped New York simplify and streamline renewable siting.

Figure 4: Great Lakes near-zero-emissions steel policy gap analysis



Moving Forward, Ohio must seek to build upon the federal legislative efforts to advance near-zero-emissions steel production. Thus far, major investments in near-zero-emissions steel production in Europe and Canada have received public funding support from national and local governments. The US federal government has provided multiple subsidy and tax incentive programs targeted at near-zero-emissions steel production, but more incentives and infrastructural support from states can expedite asset development. State policymakers, economic development offices, and developers should focus on the following areas to advance near-zero-emissions steel production in Ohio:

1. **Leveraging existing BF-BOF infrastructure for DRI-EAF development.**
2. **Avoiding large capital investments that extend the life of the Middletown and Cleveland BF-BOF assets (reline, CCS, etc.).**
3. **Including steel production as a prioritized off-take sector for hydrogen development projects.**
4. **Advancing policies that facilitate industrial access to cost-competitive renewable energy resources and repealing initiatives included in HB6.**