Economic Impact Analysis for the Proposed National Emission Standards for Hazardous Air Pollutants: Taconite Iron Ore Processing Amendments

EPA-452/R-23-003
April 2023

Economic Impact Analysis for the Proposed National Emission Standards for Hazardous Air Pollutants: Taconite Iron Ore Processing Amendments

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Health and Environmental Impacts Division
Research Triangle Park, NC

CONTACT INFORMATION

This document has been prepared by staff from the Office of Air and Radiation, U.S. Environmental Protection Agency. Questions related to this document should be addressed to the Air Economics Group in the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Office of Air and Radiation, Research Triangle Park, North Carolina 27711 (email: OAQPSeconomics@epa.gov).

ACKNOWLEDGEMENTS

In addition to U.S. Environmental Protection Agency staff, personnel from RTI International contributed research, data, and analysis to this document.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

The U.S Environmental Protection Agency (EPA) is proposing amendments to the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for facilities in the Taconite Iron Ore Processing source category (40 CFR Part 63, 40 CFR part 63, subpart RRRRR). Facilities in the Taconite Iron Ore Processing source category mine and process iron ore from taconite and produce taconite pellets, which are used as feedstock to blast furnaces at integrated iron and steel manufacturing facilities. The blast furnace reduces taconite pellets and other iron-bearing inputs to molten pig iron, which is fed to a basic oxygen furnace and used to produce steel. This document presents the economic impact analysis (EIA) for this proposed rule.

Specifically, the EPA is proposing to set or revise NESHAP requirements for mercury (Hg) and acid gas (hydrogen chloride (HCl) and hydrogen fluoride (HF)) emissions from indurating furnaces at taconite iron ore processing facilities. The proposed Hg standard addresses a regulatory gap in the NESHAP. The proposal also includes compliance testing and revisions to monitoring and operating requirements for control devices. The proposed amendments would cumulatively reduce projected emissions of Hg from this source category by 500 pounds (lbs) per year, HCl by 710 short tons per year, and HF by 38 short tons per year. Taconite processing facilities are projected to incur $91 million in total capital investment and $54 million in total annualized cost per year to meet the emission limits and other requirements in the proposal.

This EIA analyzes the costs and emissions impacts under the proposed requirements, a less stringent set of alternative requirements, and a more stringent set of alternative requirements. The projected impacts of the proposed rule and regulatory alternatives are presented for the 2027 to 2036 time period. These regulatory alternatives are discussed in Section 3.3. This EIA analyzes less and more stringent alternative options to better inform EPA and the public about the projected impacts of the proposed rule, and these results are included at EPA's discretion.

1.1 Background

1.1.1 *Statutory Requirements*

The statutory authority for the proposed NESHAP amendments is provided by sections 112 and 301 of the Clean Air Act (CAA), as amended (42 U.S.C. 7401 *et seq*.). Section 112 of the CAA establishes a two-stage regulatory process to develop standards for emissions of HAP from stationary sources. Generally, the first stage involves establishing technology-based standards, and the second stage involves evaluating those standards that are based on maximum achievable control technology (MACT) to determine whether additional standards are needed to address any remaining risk associated with HAP emissions. This second stage is commonly referred to as the "residual risk review." In addition to the residual risk review, the CAA also requires the EPA to review standards set under CAA section 112 every 8 years and revise the standards as necessary taking into account any "developments in practices, processes, or control technologies." This review is commonly referred to as the "technology review," and is the subject of this proposal.

In the first stage of the CAA section 112 standard setting process, the EPA promulgates technology-based standards under CAA section 112(d) for categories of sources identified as emitting one or more of the HAP listed in CAA section 112(b). Sources of HAP emissions are either major sources or area sources, and CAA section 112 establishes different requirements for major source standards and area source standards. "Major sources" are those that emit or have the potential to emit 10 tons per year (tpy) or more of a single HAP or 25 tpy or more of any combination of HAP. All other sources are "area sources." For major sources, CAA section 112(d)(2) provides that the technology-based NESHAP must reflect the maximum degree of emission reductions of HAP achievable (after considering cost, energy requirements, and non-air quality health and environmental impacts). These standards are commonly referred to as MACT standards. CAA section 112(d)(3) also establishes a minimum control level for MACT standards, known as the MACT "floor." In certain instances, as provided in CAA section 112(h), the EPA may set work practice standards in lieu of numerical emission standards. The EPA must also consider control options that are more stringent than the floor. Standards more stringent than the floor are commonly referred to as beyond-the-floor standards.

1.1.2 *Regulatory Background*

The sources affected by the current NESHAP for the Taconite Iron Ore Processing source category (issued under 40 CFR part 63, subpart RRRRR) are taconite iron ore processing facilities that are major sources of HAP. Taconite iron ore processing facilities separate and concentrate iron ore from taconite, a low-grade iron ore, and produce taconite pellets, which are approximately 60 percent iron and are used primarily as feedstock to iron-smelting blast furnaces at integrated iron and steel manufacturing facilities. Taconite iron ore processing facilities process both magnetite (Fe_3O_4) and hematite (Fe_2O_3) iron ore. There are seven facilities currently producing taconite pellets that will be affected by this proposed rule and are anticipated to incur costs: six in Minnesota and one in Michigan.

40 CFR part 63, subpart RRRRR applies to each new or existing ore crushing and handling operation, ore dryer, indurating furnace, and finished pellet handling operation at each major source taconite iron ore processing plant and covers emissions from ore crushing and handling emission units, ore dryer stacks, indurating furnace stacks, finished pellet handling emission units, and fugitive dust emissions. The primary HAP covered by the original NESHAP include HAP metals (e.g., manganese, arsenic, and lead), acid gases (HCl and HF), and products of incomplete combustion (e.g., formaldehyde). Indurating furnaces are the most significant sources of HAP emissions at taconite iron ore processing facilities. Two types of indurating furnaces are in use within the source category: straight grate furnaces and grate kiln furnaces.

The NESHAP for Taconite Iron Ore Processing facilities was originally finalized on October 30, 2003. EPA performed a residual risk and technology review (RTR) for the source category, which was finalized July 28, 2020. As a result of the RTR, EPA proposed no significant changes to the original NESHAP and determined that the standards provided an ample margin of safety to public health and the environment. On April 21, 2020, while EPA prepared the final RTR for signature, the D.C. Circuit Court issued a decision in *Louisiana Environmental Action Network (LEAN) v. EPA* (955 F.3d 1088 (D.C. Cir. 2020)) which held that EPA must establish standards for all listed HAP known to be emitted from a source category. Any new MACT standards related to gap-filling must be established under CAA sections 112(d)(2) and (d)(3), or, in specific circumstances, under CAA sections 112(d)(2) or (h). This decision created an obligation to regulate Hg emissions from indurating furnaces at taconite iron ore processing facilities under the NESHAP and prompted a reconsideration of the technology review for the source category.

1.1.3 *Proposed Requirements*

The proposed amendments to 40 CFR part 63, subpart RRRRR regulate Hg and acid gas emissions from indurating furnaces by setting numerical MACT-floor limits for each pollutant.

EPA is also proposing compliance testing (performed initially and every 2.5 years thereafter), and revisions to monitoring and reporting requirements for control devices. Hg emissions from indurating furnaces are currently unregulated, while acid gas emissions are currently regulated using particulate matter (PM) emissions as a surrogate.

The EPA is proposing a production-based MACT floor emissions limit for Hg based on the upper prediction limit (UPL) of the top five performing indurating furnaces at taconite facilities. The proposed MACT floor is 1.89 x 10^{-6} lb Hg/long ton pellets for new sources and 1.26 x 10^{-5} lb Hg/long ton pellets for existing sources. The MACT floor limit would apply to average furnace emissions at a facility. Because the limit applies to average furnace emissions rather than each individual furnace, the MACT floor is 10 percent more stringent than the UPL of the top five performing furnaces.

The EPA is also proposing MACT-floor limits for acid gases (HCl and HF). The proposed MACT-floor limit for HCl is 4.4 x 10^{-4} lb HCl/long ton for new sources and 6.4 x 10^{-3} lb HCl/long ton for existing sources. The proposed MACT-floor limit for HF is 4.1 x 10^{-4} lb HF/long ton for new sources and 6.3 x 10^{-3} lb HCl/long ton for existing sources. Acid gas emissions from indurating furnaces are currently controlled using PM emissions as a surrogate. For each straight grate indurating furnace processing magnetite, the current PM emissions limit is 0.006 grains/dry standard cubic foot (gr/dscf) for new straight grate furnaces and 0.010 gr/dscf for existing straight grate furnaces. For each grate kiln indurating furnace processing magnetite, the current PM emissions limit is 0.006 gr/ dscf for new grate kiln furnaces and 0.011 gr/dscf for existing grate kiln furnaces. For each grate kiln indurating furnace processing hematite, the current PM emissions limit is 0.018 gr/dscf for new grate kiln furnaces and 0.025 gr/dscf for existing grate kiln furnaces.

1.1.4 *Economic Basis for this Rulemaking*

Many regulations are promulgated to correct market failures, which otherwise lead to a suboptimal allocation of resources within a market. Air quality and pollution control regulations address “negative externalities” whereby the market does not internalize the full opportunity cost of production borne by society as public goods such as air quality are unpriced.

While recognizing that the optimal social level of pollution may not be zero, HAP emissions impose costs on society, such as negative health and welfare impacts, that are not reflected in the market price of the goods produced through the polluting process. For this regulatory action the good produced is taconite iron ore pellets, which are used as feedstock to blast furnaces in integrated iron and steel manufacturing plants. If the process of mining taconite iron ore and processing it for use in steel production pollutes the atmosphere, the social costs imposed by the pollution will not be borne by the polluting firm but rather by society as a whole. Thus, the producer is imposing a negative externality, or a social cost from these emissions, on society. The equilibrium market price of iron ore and steel products may fail to incorporate the full opportunity cost to society of using taconite as an input in steel products. Consequently, absent a regulation or some other action to limit emissions, producers will not internalize the negative externality of pollution due to emissions and social costs will be higher as a result. This regulation will work towards addressing this market failure by causing affected producers to begin internalizing the negative externality associated with HAP emissions.

1.2 Proposed Amendments

1.2.1 *Baseline and Regulatory Options*

The impacts of regulatory actions are evaluated relative to a baseline that represents the world without the regulatory action. In this EIA, we present results for the proposed amendments to the NESHAP for taconite iron ore processing facilities relative to a world without the proposed amendments. The proposed amendments set numerical MACT-floor emission limits for Hg, HCl, and HF emissions from indurating furnaces. The proposed requirements are presented in Table 1-1 below.

Table 1-1: Current and Proposed Standards for Hg and Acid Gas Emissions from Taconite Indurating Furnaces

<table>
<tr><th>Regulated Pollutant</th><th>Current Standard</th><th>Proposed Standard</th></tr>
<tr><td>Hg</td><td>No current standard</td><td>New Sources: 1.89e^{-6} lb Hg/long ton pellets
Existing Sources: 1.26e^{-5} lb Hg/long ton pellets for existing sources[a]</td></tr>
<tr><td>HCl</td><td rowspan="2">PM surrogate standard for both HCl/HF

Straight grate indurating furnace (Magnetite)

New Sources: 0.006 gr/dscf
Existing sources: 0.010 gr/dscf

Grate kiln indurating furnace (Magnetite, Hematite)

New Sources: 0.006 gr/dscf, 0.018 gr/dscf
Existing sources: 0.010 gr/dscf, 0.025 gr/dscf</td><td>New Sources: 4.4 x 10^{-4} lb HCl/long ton
Existing Sources: 6.4 x 10^{-6} lb HCl/long ton</td></tr>
<tr><td>HF</td><td>New Sources: 4.1 x 10^{-4} lb HF/long ton
Existing Sources: 6.3 x 10^{-6} lb HF/long ton</td></tr>
</table>

[a] This standard applies to average indurating furnace emissions at a facility.

Throughout this document, the EPA focuses the analysis on the proposed requirements that result in quantifiable compliance cost or emissions changes compared to the baseline. We assume each facility achieves emissions control meeting current standards and estimate emissions reductions and cost relative to this baseline. We also analyze a less stringent and more stringent alternative regulatory option as compared to our proposed option. The results of this analysis are presented alongside analysis of the proposed option in Chapter 3.

1.2.2 *Methodology*

The impacts analysis summarized in this EIA reflects a nationwide engineering analysis of compliance cost and emissions reductions. Using survey response and testing data collected from each taconite facility in a request for information conducted under CAA Section 114, the EPA estimated costs and emissions reductions of the proposed and alternative regulatory options based on the indurating furnaces at each facility and stack testing data from each furnace. We calculate cost and emissions impacts of the proposed and alternative regulatory requirements over a 10-year analytical timeframe from 2027 to 2036. This timeframe spans the projected first year of full implementation of the proposed NESHAP amendments (under the assumption that the proposed action is finalized in 2023) and presents 10 years of potential regulatory impacts. We assume the number of active facilities in the source category is constant over the analysis period.

1.3 Organization of this Report

The remainder of this report details the methodology and the results of the EIA. Chapter 2 presents a profile of the taconite iron ore processing industry. Chapter 3 describes emissions, emissions control options, and engineering costs. Chapter 4 presents analyses of economic impacts and a discussion of employment and small business impacts. Chapter 5 contains the references for this EIA.

2 INDUSTRY PROFILE

2.1 Introduction

This industry profile supports the EIA of the proposed amendments to the NESHAP for taconite iron ore processing facilities. The North American Industry Classification System (NAICS) code for iron ore mining is 21221, and all taconite mining and processing operations fall within this classification.

Taconite is the primary source of iron ore mined domestically, making up 98 percent of the iron ore market in the United States. Taconite is a low-grade iron ore, with an iron content between 20 percent and 30 percent; it only became an economically viable source of iron because of decreases in the supply of high-grade ore and innovations in extracting iron ore from taconite. The low-grade ore is processed and concentrated to reach the 62.5 percent iron content benchmark required for steel production (Tuck, 2022a). It is found nearly exclusively in hard, fine-grained, banded iron formations along the coast of Lake Superior in Minnesota and Michigan. These two states account for virtually all domestic production and have seven mining and processing operations, all of which are owned by two parent companies: Cleveland-Cliffs (five facilities) and US Steel (two facilities). The seven operations are open-pit mines and were estimated to employ 4,200 people total in 2021 (Tuck, 2022a). Each operation has associated concentration and pelletizing plants. The United States produces more iron ore than it consumes, producing 1.8 percent of the world's supply and consuming 1.4 percent. Relatively low consumption of iron ore in the United States is the result of a declining reliance on traditional blast oxygen process furnace (BOPF) steelmaking (a process that uses iron ore as a primary input). In 2021, the share of steel produced by BOPFs was estimated to be 28 percent, down from 37.3 percent in 2015, as a result of increased reliance on electric arc furnaces, which are more energy efficient, have reduced environmental impacts, and use the United States' readily available supply of steel scrap (Tuck, 2022c).

Iron ore demand is fully dependent on the demand for steel, which fell sharply in 2020 because of the economic slowdown resulting from the COVID-19 pandemic. Production fell from 47 million metric tons in 2019 to 38 million in 2020—a drop of 19 percent (Tuck, 2022a). Estimates for 2021 show a near total rebound of domestic iron ore production to pre-pandemic levels, back up to 46 million metric tons (Tuck, 2022c).

2.2 Supply Side

Domestic iron ore supply reliably meets domestic demand, and the United States was a net exporter in 2021 as it has been each year since 2007 (Tuck, 2022b). Seven open-pit taconite mines in Minnesota and Michigan account for nearly all of the domestic production of iron ore. Minnesota accounts for 83 percent of production of the national output of iron ore and Michigan accounts for 17 percent (Tuck, 2022a). These facilities not only mine the ore but also perform beneficiation and agglomeration of the ore to achieve a final pellet product that is shipped more easily. The process is explained in the following subsections.

2.2.1 *Taconite Pellets*

Low-grade taconite ore from the upper midwestern United States is the primary source of blast furnace (BF) steelmaking in the United States. Nearly all of the taconite mined in the country is processed on site and turned into pellets that are shipped to steelmaking operations.

2.2.1.1 Mining

Taconite iron ore is mined from the Mesabi Iron Range of northern Minnesota and the Marquette range in the Upper Peninsula of Michigan. The ore is mined from open pits because ore lies close to the surface in this region. The process includes overburden removal, drilling, blasting with explosives, and removal of taconite and excess rock with large trucks. Large holes, about 50 feet deep and 16 inches wide, are drilled and filled with explosives to break apart large chunks of rock. The rock that contains crude is then transported by truck or train to an on-site crushing facility. Further processing is done, explained below in Section 2.2.1.2 and Section 2.2.1.3, to separate iron ore from the crude material. Details of crude material mined and iron ore extracted are reported in Table 2-1. 2020 (during COVID-19) and 2019 (pre-COVID-19) data are shown in the table to display the drop in production stemming from the COVID-19 pandemic. Although detailed 2021 data are not yet available, total ore production nearly rebounded fully to pre-pandemic levels in 2021 to 46 million metric tons.

Table 2-1: Iron Ore Mined and Pelletized in the United States (metric tons)

Year	Region and State	Number of Mines	Crude Ore	Iron Ore
2020	Lake Superior			
	Minnesota	6	107,000	31,700
	Michigan	1	19,000	6,400
	Total	7	126,000	38,100
2019	Lake Superior			
	Minnesota	6	135,000	39,100
	Michigan	1	22,700	7,800
	Total	7	158,000	46,900

Source: Tuck (2021). *Iron Ore* [tables only release]. USGS Minerals Yearbook 2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.

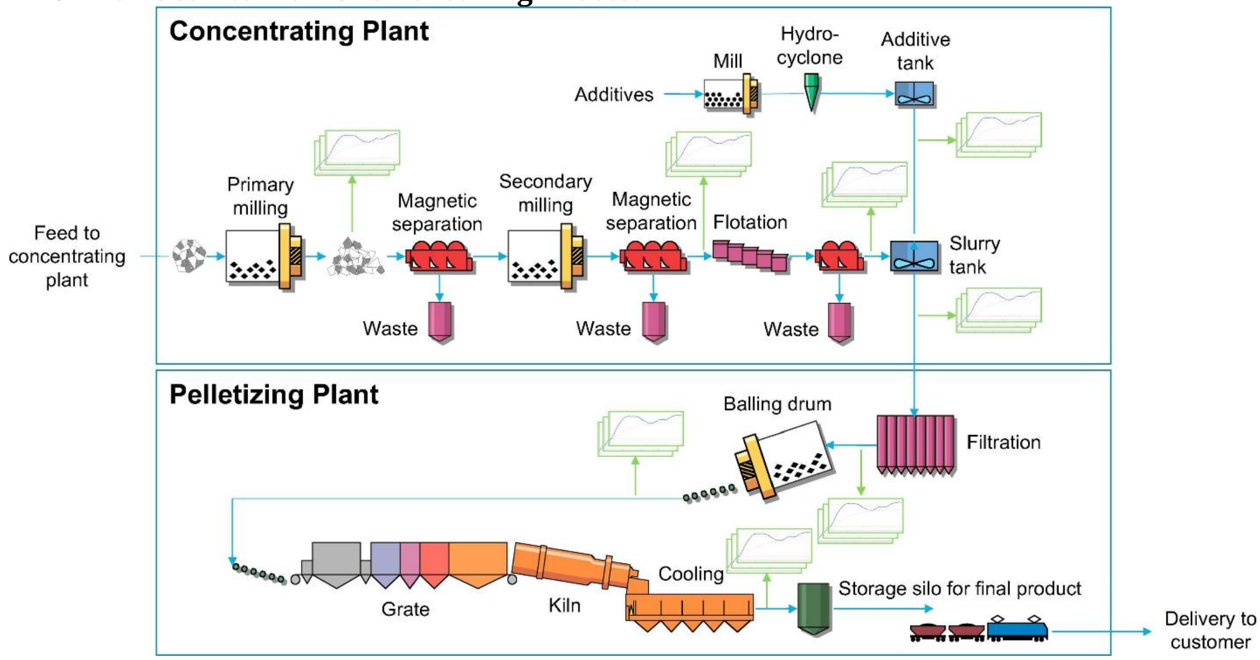
2.2.1.2 Beneficiation

The iron ore is beneficiated to remove impurities, increase the iron content, and improve the final product generally to meet the needs of steel producers. Beneficiation is achieved by crushing and grinding the rock, screening, sifting, washing, and otherwise separating impurities from the ore minerals. Once milled, the resulting slurry is passed through a process of magnetic separation to isolate iron ore from unwanted rock. Material that is not collected by the magnetic processing is called gangue or tailings, which are then reground and reprocessed to extract as much usable ore as possible. Water is removed from the iron slurry, and chemicals are added to upgrade the iron concentrates by removing impurities. The resulting concentrate is the primary input of taconite pellets.

2.2.1.3 Agglomeration

Agglomeration is the process that turns the iron-rich concentrate material into pellets by combining it with clay. This product is then rolled into marble-sized balls and heated at a high temperature by an indurating furnace. As the balls cool, they harden into the final product: taconite pellets. Taconite pellets are the primary product of iron ore facilities in the United States. An example of the pelletizing process is shown in Figure 2-1.

Figure 2-1: The Taconite Iron Ore Pelletizing Process



Source: Engström, K., & Esbensen, K. H. (2018). Evaluation of sampling systems in iron ore concentrating and pelletizing processes – Quantification of total sampling error (TSE) vs. process variation. *Minerals Engineering, 116*, 203–208. https://doi.org/10.1016/j.mineng.2017.07.008.

2.2.2 *Products*

Virtually all of domestically produced iron ore is pelletized before shipment. Pellets can take the form of standard "acid" pellets or "fluxed/partially fluxed" pellets. Standard taconite pellets are made of iron ore, oxygen, and silica and held together by clay. Fluxed pellets are simply taconite pellets with additional limestone or other basic flux additive.[1] Fluxed pellets eliminate the need to incorporate limestone in the blast furnace later in the process, improving productivity and adding value to the pellet. Pellets are considered fluxed if they contain more than 2% limestone or other flux additive, and pellets with flux values above 0% but below 2% are considered partially fluxed (Minnesota Department of Revenue, 2022). Pellets produced in Minnesota (83 percent of U.S. production) mostly contain some flux—only 2 percent are considered acid pellets, 43 percent are fully fluxed, and 55 percent (Tuck, 2022a) are partially fluxed.

[1] "Flux" is a name for any substance introduced in the blast furnace to reduce impurities in the molten. The flux materials decompose into slag and CO2 that reacts with coke in the blast furnace to reduce the iron ore to molten iron.

2.2.2.1 By-products

During the beneficiation process detailed above, iron ore, specifically magnetite, is separated from the crushed taconite using magnets. The iron content of the taconite is low, and much of the rock is left behind during magnetic separation. The leftover content is referred to as "tailings," and over 125 million metric tons of tailings are produced annually in Minnesota alone (Oreskovich, Patelke, & Zanko, 2007). The tailings are used as fill materials for pavement in road construction in areas near taconite mines and have been used in at least 1,120 miles of roadway in northeastern Minnesota (Oreskovich, Patelke, & Zanko, 2007). The supply of taconite tailings far outpaces the demand; however, because transportation costs are prohibitive for replacing gravel or other materials typically used in pavement, excess tailings are stockpiled at the mining site. Recent technological advances allow for additional iron particles to be recovered from tailings basins and pelletized (Tuck, 2022c).

2.2.3 *Costs of Production*

Table 2-2 presents the production costs for the iron ore industry from the annual Minnesota Department of Revenue Mining Tax Guide (Minnesota Department of Revenue, 2022), which is the same source that the USGS uses for the annual Minerals Yearbook reports. Minnesota produces 83 percent of the nation's iron ore and has six of the seven mining and pelletizing operations with the other being in Michigan. The costs per metric ton from Minnesota are assumed to be representative of the industry, including the operation in Michigan, and were thus applied to total national production for the purpose of this industry profile.

Table 2-2: Total Production Costs for Iron Ore Mining, 2019-2021

	2019	2020	2021
Total cost of production (per metric ton)	$45.81	$49.05	$46.22
Total production (thousand metric tons)	46,900	38,100	46,000
Total cost (1,000 USD)	$2,148,489	$1,868,805	$2,126,120

Source:

Minnesota Department of Revenue. (2022). *Mining Tax Guide*. https://www.revenue.state.mn.us/sites/default/files/2022-10/2022_mining_guide_0.pdf.

Tuck (2022c). *Iron Ore.* USGS Mineral Commodity Summaries https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-iron-ore.pdf.

For U.S. mining operations, labor, supplies, miscellaneous beneficiation costs, and depreciation make up the total costs. Total costs in Table 2-2 were calculated by multiplying the cost of production per metric ton by total production reported by the USGS in the *Mineral*

Commodity Summary 2022 (Tuck, 2022c). We estimate total costs from the iron ore industry in the United States to be $2.15 billion in 2019, $1.87 billion in 2020, and $2.13 billion in 2021. Costs fell due to a slump in global demand, and thus production, from the COVID-19 pandemic but nearly fully rebounded in 2021. As shown in Table 2-3, the cost of supplies for mining operations makes up the bulk of total costs, representing 57 percent, 57 percent, and 58 percent in 2019, 2020, and 2021, respectively. Supplies include minerals received, explosives, fuels, electricity, and machinery, among other inputs. Miscellaneous beneficiation costs make up approximately 17 percent of total costs in a typical year. Labor costs typically make up approximately 17 percent of total costs of production, and depreciation hovers around 10 percent. Overall, beneficiation costs far outweigh the costs of mining. In 2021, mining costs were $14.15/ton, while the beneficiation cost totaled $32.06/ton, or 30 percent and 70 percent of total costs, respectively.

Table 2-3: Breakdown of Cost per Metric Ton for Iron Ore Mining, 2019-2021

	2019		2020		2021	
Costs per metric ton: [a]						
Total labor expenditures	**$7.90**	**17%**	**$7.80**	**16%**	**$7.75**	**17%**
Beneficiation labor	$4.08	9%	$3.84	8%	$3.81	8%
Mining labor	$3.82	8%	$3.96	8%	$3.94	9%
Total cost of supplies	**$26.04**	**57%**	**$27.88**	**57%**	**$26.77**	**58%**
Beneficiation supplies	$18.33	40%	$19.95	41%	$18.39	40%
Mining supplies	$7.71	17%	$7.93	16%	$8.38	18%
Total depreciation	**$4.54**	**10%**	**$6.12**	**12%**	**$3.97**	**9%**
Beneficiation depreciation	$2.97	6%	$4.02	8%	$2.14	5%
Mining depreciation	$1.57	3%	$2.10	4%	$1.83	4%
Misc. beneficiation	**$7.33**	**16%**	**$7.25**	**15%**	**$7.73**	**17%**

[a] Costs per ton gathered from Minnesota tax guide. Data on cost per ton for the single Michigan mine not available.
Source: Minnesota Department of Revenue, (2022). *Mining Tax Guide*. https://www.revenue.state.mn.us/sites/default/files/2022-10/2022_mining_guide_0.pdf

2.3 Demand Side

2.3.1 *Product Characteristics*

Taconite pellets are the primary form of iron ore produced for blast furnaces at integrated iron and steel mills in the United States. Pellets measure from 3/8 to 5/8 inches in diameter and contain 60 percent to 66 percent iron. In addition to iron, pellets typically contain silica, alumina, magnesia, manganese, phosphorous, sulfur, and moisture. It is estimated that it takes approximately 1.3 metric tons of pellets along with 0.4 metric tons of coking coal and 0.3 metric tons of steel scrap in a BF to produce 1 metric ton of steel (Tuck, 2019).

2.3.2 *Uses and Consumers*

2.3.2.1 Uses

Most iron ore is consumed at integrated iron and steel mills. There are two primary routes for steel production, which use different raw inputs. The two processes are integrated steel making, relying on traditional blast furnace and basic oxygen furnace processes (BF/BOPF), and the electric arc furnace (EAF) process. The BF/BOPF process consumes iron ore (taconite pellets) along with coal, limestone, and some steel scrap. In the United States, more than 98 percent of pellets are smelted in blast furnaces to remove residual oxygen and produce molten iron, commonly known as pig iron. Pig iron is then transferred to BOPFs, in combination with scrap steel and other materials, to create steel. Nearly all of the iron ore consumed in the United States was used for iron and steelmaking from 2017 through 2020, as shown in Table 2-4, either in BFs (which create pig iron) or steelmaking furnaces (both BOPFs and EAFs use some iron ore products). Other potential applications for iron ore include ballasts, cement production, road material, and fertilizer, but the USGS does not collect data on these uses because the vast majority of iron ore is used for steelmaking.

Table 2-4: U.S. Consumption of Iron Ore by End Use, 2017-2020 (thousand metric tons)

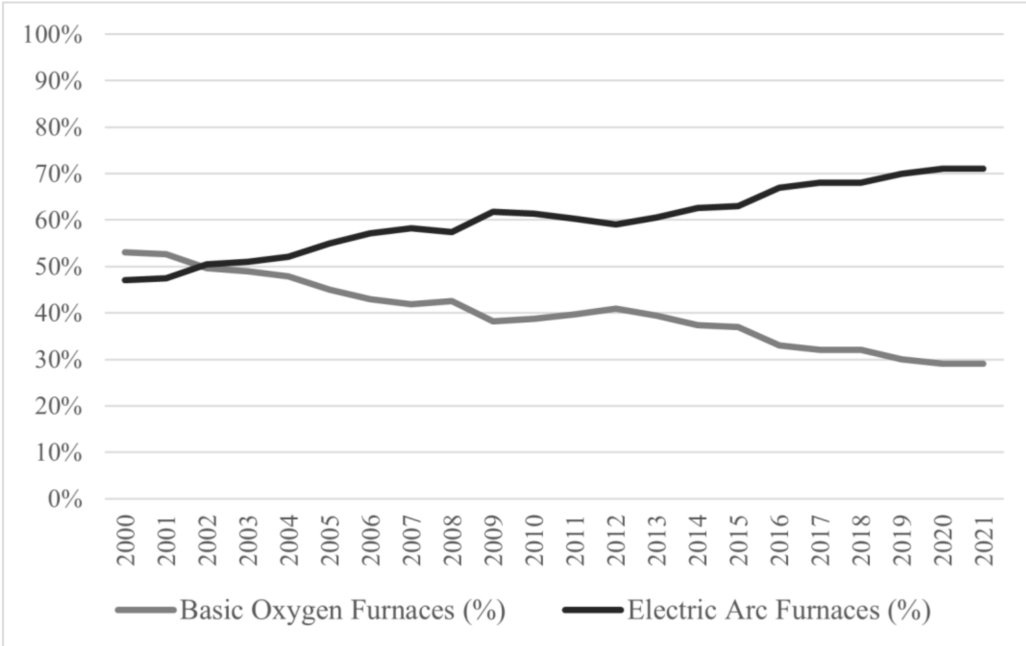
End Use/Year	2017	2018	2019	2020
Blast furnaces:				
Pellets	28,900	30,800	29,300	26,200
Sinter[a]	4,190	4,530	4,380	3,920
Total	33,100	35,300	33,600	30,100
Electric arc furnaces:				
Direct-shipping ore[b]	1,160	1,160	1,160	1,040
Sinter	159	159	--	--
Total	1,320	1,320	1,160	1,040
Grand total	**34,400**	**36,600**	**34,800**	**31,100**

[a] Sinter is another form of agglomerated iron ore and includes briquettes, nodules, and other forms.
[b] Direct-shipping ore is iron ore with high iron content that is not concentrated or beneficiated beyond crushing and screening.
Source: Tuck (2022a). *Iron Ore*. USGS Minerals Yearbook 2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.
Tuck (2019). *Iron Ore*. USGS Minerals Yearbook 2018. https://pubs.usgs.gov/myb/vol1/2018/myb1-2018-iron-ore.pdf.

The EAF process has been gaining prevalence, especially domestically, and it uses primarily recycled scrap steel and some direct-reduced iron[2] or other hot metal and electricity. In 2021, the United States relied on EAFs for 71 percent of domestic steel production and on integrated processes for 29 percent of domestic production (Tuck, 2022d). EAFs produce fewer emissions, have lower initial costs, use generally smaller operations, and are more efficient than the traditional process. Compared to the integrated steelmaking process, EAFs are quite energy efficient, using 2 gigajoules (GJ) of final energy per metric ton, compared to 15 GJ used by the integrated process (IEA, 2022). The EAF process relies primarily on electricity as an energy source, while the integrated process relies primarily on coal, resulting in vastly different emission intensities. Scrap-based EAFs, like those used in the United States, emit about 0.3 t CO_2/t of steel produced, while integrated operations emit 2.2 t CO_2/t of steel (IEA, 2020). However, EAFs typically face higher material costs than integrated steel mills because steel scrap is more expensive than iron ore. Considering raw material costs along with fuel, fixed costs, and capital costs, though, EAFs and integrated mills have similar levelized costs, according to the International Energy Agency (IEA) (2020). The United States has a long history of steelmaking and steel consumption and, thus, a mature stock of steel and steel scrap that has supported the transition to EAF production. Developing regions (China and India, for instance) tend to have newer infrastructure and less steel recycling, often along with a greater supply of iron ore or cheap coal, which favors the continued investment in integrated steelmaking. The integrated process is still the dominant steelmaking process globally, accounting for 70 percent of global production (World Steel Association, 2022). Although EAFs will continue to gain market share of steel production under a business-as-usual scenario, considering announced and existing steelmaking policies, the IEA projects that by 2050 EAFs will make up just under 50 percent of global steel production. As the industry has shifted toward EAF steelmaking, the domestic demand for iron ore has decreased over the past several decades (Figure 2-2 shows the share of EAF steelmaking over time). Section 2.5.2.4 describes the global export market for iron ore.

[2] Direct-reduced iron (DRI) is produced by removing the oxygen in iron ore in a solid state (without melting) by reacting the ore with carbon monoxide and hydrogen (typically from natural gas or goal) rather than in a blast furnace.

Figure 2-2: Share of BF/BOPF and EAF Steel in the U.S., 2001-2021



Source: USGS Mineral Commodity Summaries, 2002-2022. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

2.3.2.2 Consumers

Despite decreasing production from integrated (BF/BOPF) steelmaking, three companies and 11 integrated steel mills actively produced pig iron and raw steel in 2018 (as of the last published Minerals Yearbook from the USGS) (Tuck, 2019). The Great Lakes Works idled in 2019, and the hot strip mill, anneal, and temper operations at the Dearborn Works were permanently idled in 2020 (see Table 2-5). In 2018, the three companies operating blast furnaces in the United States were AK Steel Corporation, ArcelorMittal USA, and U.S. Steel. Since then, Cleveland-Cliffs Inc., a major producer of taconite pellets, has purchased AK Steel and ArcelorMittal, leaving just U.S. Steel and Cleveland-Cliffs Inc. as operators of integrated iron and steel mills in the United States. The main consumers of taconite pellets, thus, are U.S. Steel and Cleveland-Cliffs Inc., the only two parent companies operating taconite mines in the United States. Nearly all domestic taconite ore is produced and consumed ultimately by the same two companies.

Table 2-5: Integrated Iron and Steel Mills in the United States

Facility	Location	Owner	Raw Steel Capacity (million metric tons/year)
Gary Works	Gary, Indiana	U.S. Steel	7.5
Great Lakes Works	Ecorse, Michigan	U.S. Steel	Idled in 2019
Mon Valley Works[a]	Braddock, Pennsylvania	U.S. Steel	2.9
Granite City Works	Granite City, Illinois	U.S. Steel	2.8
Indiana Harbor Works	East Chicago, Indiana	Cleveland-Cliffs Inc.	5.5
Burns Harbor Works	Burns Harbor, Indiana	Cleveland-Cliffs Inc.	5
Middletown Works	Middletown, Ohio	Cleveland-Cliffs Inc.	3
Cleveland Works	Cleveland, Ohio	Cleveland-Cliffs Inc.	3
Dearborn Works[b]	Dearborn, Michigan	Cleveland-Cliffs Inc.	2.5

[a] Mon Valley comprises four facilities and could be considered four separate plants.
[b] Hot strip mill, anneal, and temper operation permanently idled in 2020.
Sources: US Steel and Cleveland-Cliffs websites, https://www.clevelandcliffs.com/operations/steelmaking and https://www.ussteel.com/about-us/locations.

2.3.3 *Substitution Possibilities in Consumption*

Domestic iron ore production has decreased over the past few decades as EAF steelmaking has become the dominant steelmaking process in the United States. Contributing to less than 30 percent of all steel produced domestically, integrated steel mills are the primary consumers of taconite pellets. Because EAFs will continue to benefit from a steady supply of recycled steel and have lower carbon emissions, the shift away from integrated steel production is likely to continue: from 2015 to 2021, the share of steel made through the BF/BOPF process dropped from 38 percent to 28 percent (Tuck, 2022d).

The only true substitute for domestic taconite ore in blast furnaces is imported iron ore. In 2021, 3,900 tons of iron ore were imported, but 13,000 tons were exported, making the United States a net exporter. Imports of pig iron also substitute for domestically produced pig iron, which lowers the demand for taconite pellets.

Imports of semi-finished, finished, or raw steel substitutes for domestically produced steel also lowers the demand for domestic taconite. Imports of semi-finished steel include blooms, slabs, sheets, billets, bars, and plates. The United States imported 25 million tons of steel products and 5 million tons of pig iron in 2019 (Tuck, 2022a).

2.4 Industry Organization

2.4.1 *Industry Structure*

Table 2-6 lists the seven active taconite mining and pelletizing operations in the United States as of 2021. The taconite industry is geographically concentrated on iron ranges along the coast of Lake Superior. Six of the operations mine in the Mesabi Iron Range of northern Minnesota: Minorca Mine, Hibbing Taconite Mine, Northshore Mining, United Taconite Mine, Keetac Mine, and Minntac Mine. The only remaining taconite mine outside of Minnesota is in Michigan's Upper Peninsula: Tilden Mine. U.S. Steel owns the Keetac and Minntac facilities. Cleveland-Cliffs Inc. owns the remaining five facilities.

Table 2-6: Taconite Iron Ore Facility Ownership, Capacity, Production (million metric tons), and Employment[a]

State	Facility Name	Parent Company	Annual Capacity	Production 2020	Production 2019	Employment
MN	Minorca Mine	Cleveland-Cliffs Inc.	2.9	2.8	2.8	359
	Hibbing Taconite Mine	Cleveland-Cliffs Inc.	8.1	2.5	7.6	746
	Northshore Mining	Cleveland-Cliffs Inc.	6.1	3.9	5.3	559
	United Taconite Mine	Cleveland-Cliffs Inc.	5.5	5.3	5.4	529
	Keetac Mine	U.S. Steel	5.5	2	5.3	403
	Minntac Mine	U.S. Steel	14.8	12.8	13.1	1,727
MI	Tilden Mine	Cleveland-Cliffs Inc.	8.1	6.4	7.8	838
Total			51	35.7	47.3	5,161

Source: Minnesota Department of Revenue, (2022). *Mining Tax Guide*. https://www.revenue.state.mn.us/sites/default/files/2022-10/2022_mining_guide_0.pdf

Source Tuck (2022a). *Iron Ore*. USGS Minerals Yearbook 2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.

[a] Totals may not add to total production cited earlier because of rounding and minimal production from other sites.

Estimated employment across the seven mining operations is 5,161. The size of operations varies widely, with the largest mine, Minntac, employing over 1,700 people with an annual production capacity of nearly 15 million metric tons. The smallest mine, Minorca, employs 359 people and has an annual production capacity of 2.9 million metric tons. Data on employment for the Minnesota mines were obtained from the state's Department of Revenue Annual Mining Tax Guide (Minnesota Department of Revenue, 2022), and because there is only one mine in Michigan the USGS's statewide employment estimates in the Minerals Yearbook 2020 (Tuck, 2022a) were used. The USGS Minerals Yearbook for 2020 estimates total employment at facilities in Michigan and Minnesota combined at ">4,295" people, fewer than the totals from Table 2-6 using facility-level data. The reporting for employment at the state level that the USGS cites comes from the Mining Safety and Health Administration, while the Minnesota Tax Guide gathers annual data from individual mining companies. The USGS figure is a lower bound estimate.

The industry has consolidated over the last few decades, leaving only two companies with full ownership of iron ore mining operations in the United States. In 2002, five companies owned the mines across Minnesota and Michigan, and there were four until the purchases by Cleveland-Cliffs Inc. of AK Steel in March 2020 and ArcelorMittal USA in December 2020. Now, all taconite mines and pelletizing operations are owned by either Cleveland-Cliffs Inc. or U.S. Steel. Most mining operations are wholly owned by one of the corporations, but the Hibbing Mine, located in Minnesota, is owned jointly by Cleveland-Cliffs and US Steel. When Cleveland-Cliffs Inc. bought ArcelorMittal USA in 2020, they became the majority owner and mine manager, owning 85.3 percent of the operation to U.S. Steel's 14.7 percent stake.[3]

2.4.1.1 Horizontal and Vertical Integration

Whether a firm is vertically or horizontally integrated depends on the business activity of the parent company and the businesses that the facilities or subsidiaries owned by that company engage in. Vertically integrated companies may own the production process of inputs that are used in other production processes within the company. In the taconite mining industry, a company that operates the mining and pelletizing facility might also own the integrated steel mill facility which uses the pellets produced at the mine. Horizontal integration occurs if a firm increases production of a good at the same point in the supply chain, through growth or acquisitions and mergers. Because the two companies that own taconite mines also operate integrated iron and steel mills that consume the taconite pellets, they can be considered vertically integrated (see Table 2-5 to view ownership of integrated steel mills in the United States). Cleveland-Cliffs also owns four EAF facilities. Both companies hold full or partial ownership in facilities that produce coke, with U.S. Steel owning the largest facility in the country (Clairton, located at the Mon Valley Works) (see Table 2-7). Finally, Cleveland-Cliffs owns a facility that produces hot-briquetted iron, a lower-carbon iron feedstock used primarily as a substitute for

[3] https://www.mesabitribune.com/news/local/cliffs-buys-arcelormittal-usa-in-blockbuster-deal/article_4d8e4df0-01e8-11eb-b846-67bb0579c299.html. Accessed 1/27/2023.

scrap metal in EAFs.[4] Cleveland-U.S. Steel and Cleveland-Cliffs Inc. could also be considered horizontally integrated at the taconite mining stage of production because they represent large portions of the industry. In 2019, Cleveland-Cliffs produced 61 percent of the domestic taconite ore and US Steel produced 39 percent (see Table 2-6).

Table 2-7: U.S. Coking Facility Ownership and Capacity

Parent Company	Facility	Capacity (million short tons)	Status
Cleveland-Cliffs Inc.	**Burns Harbor, IN**	**1.4**	**Active**
	Follansbee, WV	**N/A**	**Closing**
	Monessen, PA	**0.35**	**Active**
	Middletown, OH	**0.35**	**Idle**
	Warren, OH	**0.55**	**Active**
DTE Energy Company	EES-River Rouge, MI	0.8	Active
Drummond Company	ABC-Tarrant, AL	0.73	Active
James C. Justice Companies Inc.	Bluestone-Birmingham, AL	0.35	Idle
Suncoke Energy, Inc.	East Chicago, IN	1.22	Active
	Franklin Furnace, OH	1.1	Active
	Granite City, IL	0.65	Active
	Middletown, OH	0.55	Active
	Vansant, VA	0.72	Active
U.S. Steel	**Clairton, PA**	**4.3**	**Active**

Source: Firm websites.
Note: Highlighted firms also own taconite facilities.

2.4.1.2 Firm Characteristics

Table 2-8 reports 2021 sales and employment data for U.S. Steel and Cleveland-Cliffs Inc. The data provided in the table were collected from the corporations' Forms 10-K submitted to the U.S. Securities and Exchange Commission. Each company is headquartered in a traditional steel-producing city in the Midwest: Pittsburgh (U.S. Steel) and Cleveland (Cleveland-Cliffs

[4] https://www.clevelandcliffs.com/operations/steelmaking/toledo-dr-plant. Accessed 1/27/2023.

Inc.). Both companies reported similar sales revenue, both above $20 billion and both with approximately 25,000 employees worldwide.

Table 2-8: Taconite Iron Ore Facility Owner Sales and Employment, 2021

Parent Company	HQ Location	Legal Form	Sales (million USD)	Employment
U.S. Steel	Pittsburgh, PA	Public	$20,275	24,500
Cleveland-Cliffs Inc.	Cleveland, OH	Public	$20,444	26,000
Total			$40,719	50,500

Sources: U.S. Steel Corporation Form 10-K 2022 and Cleveland-Cliffs Inc. Form 10-K 2022

2.5 Markets

2.5.1 *Market Structure*

Market structure is important because it influences the behavior of producers and consumers within an industry and affects the incidence of costs associated with a regulation that is imposed on an industry. In a perfectly competitive industry, producers are price takers and unable to influence the price of both outputs and inputs they purchase. Perfectly competitive industries typically have many firms that sell undifferentiated products, and the entry and exit of firms are unrestricted. In contrast, a noncompetitive market typically contains few firms or even a single firm, more differentiation, and limited entry and exit. In a more concentrated market, firms have the ability to influence price through exerting market power. The most extreme example of market concentration is a monopoly, where a single firm supplies the entire market and can set the price of the product. The market structure of the U.S. iron ore market is examined in the following sections.

There are indices that measure market concentration of certain industries, but little economic literature focuses on the concentration of the domestic iron ore industry. Germeshausen et al. (2015) analyzed the extent of several firms' market power on a global scale and found that price setting, or markups, is likely. Küblböck et al. (2022) also noted that the industry is concentrated at a global scale, with four companies controlling more than 70 percent of the iron ore export market. Domestically, as noted above in Table 2-6, only two companies control all of the taconite mining and pelletizing process and integrated steelmaking that consumes taconite pellets. With two vertically integrated companies controlling extraction and consumption of taconite and significant barriers to entry to mining a mineral that only has economically viable deposits in a few locations, the taconite industry is concentrated.

2.5.2 *Market Volumes and Prices*

2.5.2.1 Domestic Production and Consumption

Table 2-9 provides domestic production of usable iron ore, consumption, and prices from 2010 through 2021. Production hit a low in 2020 of 38 million metric tons because of the drop in demand caused by the Covid-19 pandemic. Ignoring the outlier pandemic year, domestic production has been dropping over the time frame shown, besides 2010, and also has dropped significantly from the 1990s, when production floated between 55 million and 62 million metric tons (U.S. EPA, 2003b). Production also surpassed consumption in each year shown in Table 2-9, a deviation from past decades as demand for iron ore dropped domestically due to the surge in EAF steelmaking. In the 1990s, for instance, consumption was typically 10 to 25 million metric tons greater than domestic production and the United States relied on imports of iron ore to meet higher demand.

Table 2-9: Domestic Production, Consumption, and Prices, 2010-2021

Year	Ore Production (thousand metric tons)	Shipment Quantity (thousand metric tons)	Consumption (thousand metric tons)	Unit Value (Price $/ton)	Unit Value (Price $/ton, 2021$)[a]
2010	49,900	50,600	48,000	$98.79	$117.89
2011	56,200	56,900	47,500	$104.10	$110.39
2012	54,700	53,900	47,100	$116.48	$113.09
2013	52,800	53,400	47,600	$87.42	$120.75
2014	56,100	55,000	47,900	$84.43	$109.37
2015	46,100	43,500	42,100	$81.19	$107.97
2016	41,800	46,600	37,900	$73.11	$103.26
2017	47,900	46,900	40,100	$78.54	$104.58
2018	49,500	50,400	41,400	$93.00	$119.38
2019	46,900	47,000	39,100	$92.94	$112.11
2020	38,100	38,000	31,100	$91.27	$107.76
2021	46,000	44,000	36,000	$94.00	$94.00

[a] Inflation adjustments made using U.S. Bureau of Labor Statistics, Producer Price Index by Industry: Iron Ore Mining [PCU2122121221].

Sources: USGS, Minerals Yearbook 2010–2020; USGS Minerals Commodities Summary - 2022.

2.5.2.2 Prices

Prices are shown as unit values in Table 2-9, or total value of production divided by metric tons produced. Note that the iron ore prices are the values of the usable ore at mines, which do not include mine-to-market transportation costs. Prices adjusted for inflation are shown in 2021 dollars using the Producer Price Index for iron ore mining. Prices in 2021 dollars are relatively steady across the 2010s, ranging between $103/ton in 2015 and $120/ton in 2013.

2.5.2.3 Supply and Demand Elasticities

Elasticities are measures of how responsive demand and supply are to the price of a good. If the price increases for iron ore, for example, how much demand decreases is the elasticity of demand for iron ore. A consistent finding in the economics literature is that the demand for iron ore is likely price inelastic, or nonresponsive to changes in price. An estimate of −0.3 for iron ore means that if price increases by 1%, the demand for iron ore falls 0.3%. If the absolute value of an elasticity is greater than 1, that good is considered price elastic. Table 2-10 provides supply and demand elasticities for domestic and foreign taconite pellets and steel mill products that have been used in past EPA analyses of the iron and steel industry, along with more recent values found in the economics literature when available.

Table 2-10: Supply and Demand Elasticities of Iron Ore and Steel Mill Products

	Supply Elasticity	Demand Elasticity
Iron ore	0.5[a]	−0.241[b]
	0.45[b]	−0.30[a]
	1.08[c]	
Foreign	1.08[c]	−0.92[c]
Steel	0.7–1.2[d]	−0.079[e]
	3.5[c]	−0.59[c]
Foreign	3–6 (Mexico or Canadian imports) 10–20 (all other imports)[f] 15[c]	−1.25[c]

[a] Fisher, B. S., Beare, S., Matysek, A. L., & Fisher, A. (2015). The impacts of potential iron ore supply restrictions on producer country welfare. BAE Economics. Available at: http://www.baeconomics.com.au/wp-content/uploads/2015/08/Iron-Ore-Spatial-Equilibrium-Model-8Aug15.pdf.

[b] Zhu, Z. (2012). Identifying supply and demand elasticities of iron ore. Duke University, Durham, NC. Available at: https://sites.duke.edu/econhonors/files/2013/09/thesis_final_zhirui_zhuv21.pdf.

[c] Environmental Protection Agency. (2003). Taconite iron ore NESHAP economic impact analysis. Environmental Protection Agency. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100D5QR.pdf.

[d] Mathiesen, L., & Maestad, O. (2004). Climate policy and the steel industry: Achieving global emission reductions by an incomplete climate agreement. The Energy Journal, 25, 91–114. Available at: https://doi.org/10.2307/41323359

[e] Fernandez, V. (2018). Price and income elasticity of demand for mineral commodities. Resources Policy, 59, 160–183. Available at: https://doi.org/10.1016/j.resourpol.2018.06.013.

[f] Fetzer. J. J. (2005). A partial equilibrium approach to modeling vertical linkages in the U.S. flat rolled steel market. U.S. International Trade Commission. Office of Economics Working Paper No. 2005-01-A. Available at: https://www.usitc.gov/publications/332/ec200501a.pdf.

2.5.2.4 Foreign Trade

Table 2-11 provides data on the total quantity and value of iron ore imports for each year from 2010 through 2020, with quantity also reported for 2021. The quantity of imports ranged from approximately 3 million metric tons in 2013 to 6.4 million metric tons in 2010, and the average annual imports over this decade totaled 4.2 million metric tons. The value of imports adjusted to 2021 dollars ranged from $340 million in 2016 to $891 million in 2011. The overall trend is apparent: imports of iron ore are dropping as demand decreases. From 1990 to 2001, the United States imported over 3 times as much iron ore as the most recent decade, 15 million metric tons a year on average. Table 2-12 shows which countries the United States imported from and the kinds of products imported. Pellets made up 90 percent of the iron ore products imported, and Brazil, Canada, and Sweden were responsible for 55 percent, 20 percent, and 9 percent, respectively, of iron ore imported to the United States.

Table 2-13 provides data on both quantity and value of exports from the United States between 2010 and 2020, with quantity only updated so far for 2021. The export trend is the opposite of the import story told above. From 1990 to 2002, the average volume of iron ore exports was about 5 million metric tons, and from 2010 to 2021, the average volume was double that, at 10.8 million metric tons. There is no glaring trend from 2010 to 2021 in terms of quantity of ore exported, but it has remained relatively steady. Table 2-14 shows where the United States sent iron ore and the most common exports. Canada, China, and Japan consumed 60 percent, 19 percent, and 7 percent of the United States' exports, respectively. Pellets made up 77 percent of exported products, while iron ore concentrates (non-pelletized) made up 21 percent. The United States has been a net exporter of iron ore since 2007.

Table 2-11: Iron Ore Imports and Value of Imports, 2010-2021

Year	Imports (1,000 metric tons)	Total Value (1,000 USD)	Total Value ($2021; 1,000 USD)	Value ($/metric ton)	Value (2021$; $/metric ton)
2010	6,420	$703,000	$838,902	$109.50	$130.67
2011	5,270	$841,000	$891,835	$159.58	$169.23
2012	5,160	$759,000	$736,893	$147.09	$142.81
2013	3,250	$426,000	$588,398	$131.08	$181.05
2014	5,140	$676,000	$875,648	$131.52	$170.36
2015	4,550	$455,000	$605,053	$100.00	$132.98
2016	3,010	$241,000	$340,395	$80.07	$113.09
2017	3,710	$356,000	$474,035	$95.96	$127.77
2018	3,810	$388,000	$498,074	$101.84	$130.73
2019	3,980	$499,000	$601,930	$125.38	$151.24
2020	3,240	$389,000	$459,268	$120.06	$141.75
2021	3,900	NA	NA	NA	NA

Sources: U.S. Bureau of Labor Statistics, Producer Price Index by Industry: Iron Ore Mining [PCU2122121221].
USGS, Minerals Yearbook 2010–2020.
USGS Mineral Commodities Summary 2022.

Table 2-12: Iron Import Value by Country and Product, 2021

	Value (1,000 USD)	Share (%)
Imports from:		
Brazil	$410,000	55%
Canada	$153,000	20%
Sweden	$69,400	9%
Other	$117,000	16%
Total	$750,000	100%
Type of Import:		
Concentrates	$35,300	5%
Fine ores	$37,900	5%
Pellets	$673,000	90%
Other	$3,960	1%
Total	$750,000	100%

Source: USGS (2022). *Iron Ore*. Mineral Industry Surveys – Dec. 2021. Available at https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.

Table 2-13: Iron Ore Exports by Value, 2010-2021

Year	Exports (1,000 metric tons)	Total Value (1,000 USD)	Total Value ($2021; 1,000 USD)	Value ($/metric ton)	Value (2021$; $/metric ton)
2010	9,950	$1,090,000	$1,300,716	$110.00	$131.00
2011	11,100	$1,330,000	$1,410,392	$120.00	$127.00
2012	11,200	$1,440,000	$1,398,058	$129.00	$125.00
2013	11,000	$1,480,000	$2,044,199	$135.00	$186.00
2014	12,100	$1,320,000	$1,709,845	$109.00	$141.00
2015	7,510	$611,000	$812,500	$81.00	$108.00
2016	8,710	$574,000	$810,734	$66.00	$93.00
2017	10,600	$766,000	$1,019,973	$72.00	$96.00
2018	12,700	$972,000	$1,247,754	$77.00	$98.00
2019	11,400	$982,000	$1,184,560	$86.00	$104.00
2020	10,400	$839,000	$990,555	$81.00	$95.00
2021	13,000	NA	NA	NA	NA

Sources: U.S. Bureau of Labor Statistics, Producer Price Index by Industry: Iron Ore Mining [PCU2122121221].
USGS, Minerals Yearbook 2010–2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.
USGS Minerals Commodities Summary 2022. Available at: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-iron-ore.pdf.

Table 2-14: Iron Export Value by Country and Product, 2021

	Value (1,000 USD)	Share (%)
Exports to:		
Canada	$767,000	60%
China	$240,000	19%
France	$7,700	1%
Japan	$89,500	7%
Netherland	$23,800	2%
Spain	$41,900	3%
Other	$117,000	9%
Total	$1,290,000	100%
Type of Export:		
Concentrates	$265,000	21%
Fine ores	$532	0%
Pellets	$995,000	77%
Other	$27,300	2%
Total	$1,290,000	100%

Sources: USGS (2022). *Iron Ore*. Mineral Industry Surveys – Dec. 2021. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.

2.5.3 *Market Forecasts*

Iron ore remains one of the most important commodities globally because steel is vital to the global economy. The United States has considerable iron resources remaining, estimated to be approximately 110 billion metric tons of iron ore containing about 27 billion metric tons of iron (Tuck, 2022c). Yet, as mentioned previously, the share of steel produced in the United States using the BF/BOPF production process (which uses taconite iron ore) continues to decrease as a result of growth in production by EAFs, which offer a more energy-efficient and environmentally-friendly option. The BF/BOF steel production route has declined from 85 percent in 1970 to about 50 percent in 2000 and more recently from 37 percent in 2015 to 28 percent in 2021. This trend is likely to continue in the United States as investment in EAFs (sometimes called mini-mills) continues to grow. Canada, the United States' primary export market for iron ore, has also seen declining rates of steel production at integrated steel mills (over 21 percent in the last 20 years (Cheminfo Services Inc., 2019)). The outlook for integrated steel production in Canada is not promising. Production will likely continue to decline in the face of reduced manufacturing in-country and increased reliance on imported steel.

As detailed in the Organisation for Economic Co-operation and Development's recent report *Latest Developments in Steelmaking Capacity 2021* (2021), companies invested in 11 new steelmaking facilities in the United States to start production in 2020 or later, all of which are EAFs. Although BF/BOF facilities are still being constructed in India, China, and parts of Africa and Asia, it appears unlikely that BF/BOPF capacity will increase in the United States in the near future. As shown in Table 2-5, two integrated iron and steel facilities have idled over the past 3 years, and another one closed in 2015 that now houses an EAF. As the United States, as well as other countries, attempts to reduce carbon emissions to meet climate policy targets, EAFs may become more cost competitive because they produce 0.3 t CO_2 per metric ton of steel compared with 2.2 t CO_2 per metric ton of steel emitted by a BOPF (IEA, 2020). A 2021 IEA report projects that, by 2050, EAFs in the United States will make up about 90% of steel production (IEA, 2020).

3 EMISSIONS AND ENGINEERING COSTS ANALYSIS

3.1 Introduction

In this chapter, we present estimates of the projected emissions reductions and engineering compliance costs associated with the proposed NESHAP amendments for the 2027 to 2036 period. The projected costs and emissions impacts are based on facility-level estimates of the costs of meeting the proposed emission limits and the expected emission reductions resulting from installing the necessary controls. The baseline emissions and emission reduction estimates are based on the number and type of indurating furnaces at each facility, stack testing data, and information and assumptions about current installed controls.

3.2 Facilities and Emissions Points

3.2.1 *Taconite Iron Ore Processing Facilities*

The NESHAP for taconite iron ore processing facilities covers eight facilities: six in Minnesota and two in Michigan. One of the eight facilities, Empire, is currently idled long-term and does not have plans to resume operation in the near future. Cleveland-Cliffs Inc. owns six of these facilities (including Empire), and U.S. Steel owns two. Table 3-1 below lists these facilities.

Table 3-1: Taconite Iron Ore Processing Facilities

Ultimate Parent Company	Facility	State
Cleveland-Cliffs Inc.	Hibbing	Minnesota
	Minorca	Minnesota
	Northshore	Minnesota
	United	Minnesota
	Empire[a]	Michigan
	Tilden	Michigan
U.S. Steel	Keetac	Minnesota
	Minntac	Minnesota

[a] The Empire facility is currently idled long-term.

Taconite iron ore processing facilities engage in the following activities: mining, crushing and handling crude ore; concentrating, agglomerating, and indurating taconite pellets; and handling finished taconite pellets. While the NESHAP covers iron ore crushing and handling operations, ore dryers, indurating furnaces, and finished pellet handling within each facility, the proposed amendments only affect indurating furnaces.

3.2.2 *Indurating Furnaces, Emissions, and Current Controls*

During the indurating process, taconite pellets are hardened and oxidized in the indurating furnace at a temperature between 2,290- and 2,550-degrees Fahrenheit. Two types of indurating furnaces are in use at taconite processing facilities: straight grate furnaces and grate kiln furnaces. The main difference between a straight grate and grate kiln furnace is that a straight grate furnace performs the entire indurating process on a single piece of equipment, whereas a grate kiln furnace uses three distinct pieces of equipment: a preheat grate, a rotary kiln, and an annular cooler. There are also various technical differences that impact pellet cost and quality. Worldwide, 61 percent of installed taconite indurating capacity uses a straight grate furnace vs. 33 percent using grate kiln (in the US, the split is 50-33), with shaft furnaces and other technologies making up the remainder. For a discussion of the differences between the two types of furnaces, see Kordazadeh et al (2017).

Indurating furnaces are by far the most significant source of HAP emissions from the taconite iron ore processing source category.[5] They emit three types of HAP: metallic HAP, organic HAP, and acid gases. Metallic HAP makes up a portion of particulate emission released by the taconite ore and fuel (typically natural gas or coal) fed into the furnace. Organic HAP, primarily formaldehyde, is released due to incomplete combustion. Acid gases (HCl and HF) are formed when chlorine and fluorine present in taconite raw materials fed into the furnace are released and combine with moisture in the furnace exhaust. Each facility has installed controls to limit PM emissions. Five facilities (Hibbing, Minorca, United, Keetac, and Minntac) use wet scrubbers, Northshore uses wet electrostatic precipitators (ESP), and Tilden uses dry ESP. The proposed amendments, discussed in Section 3.3 below, would require additional controls at some facilities to increase control of Hg (a metallic HAP) and acid gases. Table 3-2 describes the type of indurating furnaces and the current controls present at each facility.

[5] This paragraph is based on information from the original NESHAP proposal (U.S. EPA, 2003a).

Table 3-2: Indurating Furnaces at Taconite Iron Ore Processing Facilities

Facility	Number of Furnaces	Type	Current Control
Hibbing	3	Straight grate	Multiclone followed by Venturi Rod Deck Wet Scrubber
Minorca	1	Straight grate	Recirculating Wet Venturi Type Scrubber
Northshore	4	Straight grate	Wet Electrostatic Precipitator
United	2	Grate kiln	Wet Scrubber
Tilden	2	Grate kiln	Dry Electrostatic Precipitator
Keetac	1	Grate kiln	Wet Scrubber
Minntac	5	Grate kiln	Once Through Wet Venturi Type Scrubber

Note: This table does not include information for Empire, because they did not respond to the CAA Section 114 Request for Information since the facility is idle.

3.2.3 *Facility Projections and the Baseline*

The impacts of regulatory actions are evaluated relative to a baseline that represents the world without the regulatory action. In this EIA, we present results for the proposed amendments to NESHAP 40 CFR part 63, subpart RRRRR for taconite iron ore processing facilities. Throughout this document, we focus the analysis on the proposed requirements that result in quantifiable compliance cost or emissions changes compared to the baseline.

For each facility, the EPA used survey response and testing data collected from each taconite facility in a request for information conducted under CAA Section 114 to inform the estimates of baseline emissions at each facility. Information used in constructing this estimate includes the number and type of indurating furnaces at each facility, the controls installed on each indurating furnace, and assumptions about the current level of emissions control achieved by the controls on each furnace. For information on the emissions data collected to support the proposed rule, see the memorandum *Emissions Data Collected in 2022 for Indurating Furnaces Located at Taconite Iron Ore Processing Plants* (Putney, 2023a), available in the docket for the proposed rule. For detailed information on the cost and emissions impact estimates for the environmental controls analyzed, see the technical memo for the proposed rule (Putney, *Development of Impacts for the Proposed Amendments to the NESHAP for Taconite Iron Ore Processing*, 2023c), also available in the docket. This memo will be referred to as the Technical Memo in subsequent sections.

For the analysis, we calculate the cost and emissions impacts of the proposed NESHAP amendments from 2027 to 2036. The initial analysis year is 2027 as we assume the proposed action will be finalized and thus become effective near the end of 2023. We assume full compliance with the proposed amendments to 40 CFR part 63, subpart RRRRR will take effect three years later in late-2026, which is consistent with the requirements in Section 112 of the CAA for HAP standards. The final analysis year is 2036, which allows us to provide 10 years of potential regulatory impacts after the proposed amendments are assumed to fully take effect. We assume the number of facilities active in the source category remains constant during the analysis period. The main uncertainty in this assumption is the status of the Empire mine. The Empire mine is currently idled long-term and does not have plans to resume operation.

3.3 Description of Regulatory Options

This EIA analyzes less and more stringent alternative regulatory options in addition to the proposed amendments to 40 CFR part 63, subpart RRRRR. This section details the regulatory options examined for both Hg and acid gases. In addition to the emission limits discussed in each section, EPA is also proposing compliance testing and monitoring, recordkeeping, and reporting requirements.

3.3.1 *Mercury (Hg)*

Hg is a metallic HAP released as a portion of PM emitted by the indurating furnace from the taconite iron ore and fuel fed into it. The amount of Hg emitted by furnace is determined largely by the Hg content of the ore processed by a furnace, and can thus vary over time for a particular furnace. There is no current emissions limit for Hg from taconite indurating furnaces.

The EPA is proposing a production-based MACT floor emissions limit for Hg based on the upper prediction limit (UPL) of the five lowest-emitting furnaces (based on stack testing data) that would apply to average furnace emissions at a facility. The five lowest-emitting furnaces include the furnaces at the Northshore and Tilden mines. Based on emissions from these furnaces, the UPL is 2.1×10^{-6} lb Hg/long ton pellets for new sources and 1.4×10^{-5} lb Hg/long ton pellets for existing sources. Because the emissions limit applies to average furnace emissions rather than each individual furnace, EPA is proposing a MACT-floor limit that is 10 percent more restrictive than the UPL of the five lowest-emitting furnaces: 1.89×10^{-6} lb Hg/ton pellets for new sources and 1.26 x 10^{-5} lb Hg/ton pellets for existing sources. This emission limit would require additional Hg control from at the Hibbing (two of three furnaces), Minorca (one of one furnace), United (one of two furnaces), Keetac (one of one furnace), and Minntac facilities. We assume in constructing the cost estimates that controlling Hg at a given furnace will require installing a new, higher-efficiency wet scrubber along with an activated carbon injection (ACI) system. For details on the cost estimates, see the Technical Memo.

This EIA also analyzes less and more stringent regulatory options for Hg. The MACT-floor limit could be set with respect each individual indurating furnace. Because furnace emissions are largely driven by the Hg content of the processed iron ore, this would require a facility to install controls for each furnace to ensure no furnace violates the standard. Based on stack testing data, EPA projects that defining the MACT-floor for Hg in this way would require additional control from the Hibbing (one additional furnace), United (one additional furnace), and Minntac (three additional furnaces). Under this option, the MACT floor limit would be set at the UPL of the five lowest-emitting furnaces (under the proposed option, the MACT floor is 10 percent more restrictive). Although this option requires additional cost and achieves additional PM reduction relative to the proposed option, it results in less Hg reduction and is therefore considered less stringent than the proposed option.

This EIA also analyzes a more stringent option for Hg: a BTF MACT limit 10 percent more restrictive than the UPL of the 5 lowest-emitting furnaces that applies to each furnace. The BTF standard for Hg is the same as the proposed standard, but it applies to each furnace rather than average facility emissions. This option would require additional controls on the same furnaces as the less stringent alternative, but would require slightly greater capital and total annualized cost. For a summary of the regulatory options for Hg presented in this EIA, see Table 3-3.

3.3.2 *Acid Gases (HCl/HF)*

Acid gases (HCl and HF) are formed when chlorine and fluorine present in taconite raw materials fed into the furnace are released and combine with moisture in the furnace exhaust. Acid gases are currently controlled in indurating furnaces using a PM surrogate standard. The EPA is proposing to replace the PM surrogate standard with numerical MACT-floor limits for acid gases (HCl and HF) that would apply to each indurating furnace. The proposed MACT-floor limit for HCl is 4.4×10^{-4} lb HCl/long ton for new sources and 6.4×10^{-3} lb HCl/long ton for existing sources. The proposed MACT-floor limit for HF is 4.1×10^{-4} lb HF/long ton for new sources and 6.3×10^{-3} lb HF/long ton for existing sources. We project that all facilities except for Tilden can meet the proposed MACT-floor standard without additional control devices. Tilden is expected to meet the proposed limit by using dry sorbent injection (using hydrated lime) (DSI) with their existing dry ESP.

This EIA also analyzes less and more stringent regulatory options for acid gases. A less stringent regulatory option for acid gases would maintain the PM surrogate standard for acid gases. This option would simply maintain the status quo and not require facilities to incur incremental cost. EPA also analyzed a more stringent regulatory alternative for acid gases: setting a BTF MACT limit 30 percent more restrictive than the MACT floor that applies to all furnaces. The BTF MACT limit for HCl is 3.08×10^{-4} lb HCl/long ton for new sources and 4.48×10^{-3} lb HCl/long ton for existing sources. The BTF MACT limit for HF is 2.87×10^{-4} lb HF/long ton for new sources and 4.41×10^{-3} lb HF/long ton for existing sources. This BTF standard for acid gases would require Tilden to use trona as sorbent in DSI to control acid gas emissions but would not require installation of additional pollution controls. All other active facilities are expected to be able to achieve the BTF MACT standard without requiring acid gas reductions. For a summary of the regulatory options for acid gases presented in this EIA, see Table 3-3.

3.3.3 *Summary of Regulatory Options*

This EIA analyzes three sets of regulatory alternatives in the emissions and engineering cost analysis presented in Sections 3.4 and 3.5: the proposed NESHAP amendments, along with less and more stringent alternative options. The three sets of alternatives are presented below in Table 3-3.

Table 3-3: Regulatory Options Examined in this EIA

Regulated Pollutant	Requirement	Regulatory Option		
		Less Stringent	Proposal	More Stringent
Hg	Numerical MACT floor limit that applies to each furnace	X		
	Numerical MACT floor limit for average facility emissions from indurating furnaces		X	
	10% beyond-the-floor limit that applies to each furnace			X
Acid Gases (HCl/HF)	Maintain PM surrogate standard for acid gases	X		
	Numerical MACT floor limit that applies to each furnace		X	
	30% beyond-the-floor limit that applies to each furnace			X

3.4 Emissions Reduction Analysis

3.4.1 *Baseline Emissions Estimates*

The baseline emissions estimates for the taconite iron ore processing source category are presented in Table 3-4 below. Estimates are presented both as emitted tons per year and over the entire analysis period 2027-2036. Note that, since the number of facilities active in the sector is assumed constant over the period, and EPA lacks data to project year to year changes in production by each facility, projected emissions for each pollutant are assumed constant for each year in the analysis period. Baseline emissions estimates are based on indurating furnace stack testing data for each facility. The figures presented for Hg equate to approximately 1,010 lbs per year and 10,100 lbs from 2027-2036. “Other HAP” emissions include arsenic, selenium, and nickel. About 86 percent of the emissions in this category are arsenic. The proposed standards are also projected to reduce emissions of PM, some of which is expected to be $PM_{2.5}$ (PM less than two microns in diameter).

Table 3-4: Baseline Emissions from Indurating Furnaces for Taconite Iron Ore Processing Source Category

	Pollutant	
Tons per Year	Hg	0.51
	HCl	1,050
	HF	130
	Other HAP	5.0
	PM	1,500
	$PM_{2.5}$	260
	SO_2	4,900
2027-2036	Hg	5.1
	HCl	10,500
	HF	1,300
	Other HAP	50
	PM	7,200
	$PM_{2.5}$	2,600
	SO_2	49,000

Note: Numbers rounded to two significant digits unless otherwise noted.

3.4.2 *Projected Emissions Reduction*

Projected emissions reductions for each pollutant are present in Table 3-5 below. The proposed NESHAP amendments are expected to reduce Hg emissions by about 49 percent, acid gas emissions by about 90 percent, and $PM/PM_{2.5}$ emissions about relative to baseline. These reductions are based on an assumption of 80-90 percent Hg removal and 99 percent PM removal achieved by a newly installed venturi wet scrubber and ACI system, along with 95 percent PM control from the existing controls at each facility. The proposed acid gas standards achieve 77 percent reduction at the Tilden facility and 69 percent reduction industry-wide (74 percent HCl reduction, 28 percent HF reduction). EPA also anticipates small reductions in $SO_{2,}$ from acid gas controls at Tilden and small reductions in arsenic, selenium, and nickel from newly-installed PM controls at facilities controlling mercury. Additional acid gas and SO_2 reductions from Tilden are achieved under the more stringent alternative by using trona instead of hydrated lime as a sorbent.

The less stringent Hg option achieves less emission reduction because even though the standard applies to each individual furnace and requires additional pollution controls, the MACT floor is less strict under this option. The BTF limit for Hg achieves additional Hg reductions relative to the proposed options by requiring each furnace to meet the BTF limit (which is identical to the standard that average furnace emissions must meet under the proposed option). Note that PM and other HAP reductions are smallest under the proposed option because fewer furnaces require new PM controls when facilities are allowed to meet the standard through furnace emissions averaging. For additional information on the methods and assumptions used to estimate emissions reductions, see the Technical Memo.

Table 3-5: Projected Emissions Reductions for Regulatory Options

		Less Stringent	Proposed	More Stringent
Tons per Year	Hg	0.23	0.25	0.26
	HCl	0	710	803
	HF	0	38	43
	Other HAP	2.7	1.7	2.7
	PM	940	490	940
	$PM_{2.5}$	160	83	160
	SO_2	0	80	61
2027-2036	Hg	2.3	2.5	2.6
	HCl	0	7,100	8,030
	HF	0	380	430
	Other HAP	27	17	27
	PM	9,400	4,900	9,400
	$PM_{2.5}$	1,600	830	1,600
	SO_2	0	800	610

Note: Numbers rounded to two significant digits unless otherwise noted.

3.4.3 *Secondary Emissions Impacts*

The proposed amendments are expected to require the installation and operation of environmental control devices which consume electricity. Air quality impacts arise from the pollutants emitted to generate the electricity needed to power the control devices. Pollutants emitted by power plants include carbon monoxide (CO), carbon dioxide (CO_2), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), methane (CH_4), and PM/$PM_{2.5}$. For estimates of the secondary emissions impacts of the proposed standards, see Table 3-6 below. Details of the estimates of energy usage by control devices and emissions increases from electricity generation are contained in the Technical Memo.

Table 3-6: Projected Secondary Emissions Impacts of the Proposed Amendments

HAP Controlled	Energy Impacts (kWh/year)	Secondary Emissions Increases (tpy)							
		CO	NO_2	PM	$PM_{2.5}$	SO_2	CO_2	CH_4	N_2O
Hg	1.0×10^8	13	35	5.2	1.6	45	46,000	4.9	0.70
HCl	4.3×10^6	0.54	1.80	0.22	0.07	0.80	3,100	0.30	0.04
Total	1.1×10^8	13	36	5.4	1.7	46	49,000	5.2	0.74

Note: Numbers rounded to two significant digits unless otherwise noted.

3.5 Engineering Cost Analysis

3.5.1 *Facility-Level Impacts Tables*

This section presents facility-level impacts tables for each regulated pollutant. All tables contain per-year figures with the exception of total capital investment. Total annualized costs include capital cost annualized using the bank prime rate in accord with the guidance of the EPA Air Pollution Control Cost Manual (U.S. EPA, 2017), operating and maintenance costs, annualized costs of increased compliance testing, and costs of R&R. Compliance testing for Hg and acid gases occurs initially and every 2.5 years thereafter, and is annualized over a 2.5-year period in calculating annualized costs. To estimate these annualized costs, the EPA uses a conventional and widely accepted approach, called equivalent uniform annual cost (EUAC) that applies a capital recovery factor (CRF) multiplier to capital investments and adds that to the annual incremental operating expenses to estimate annual costs. This cost estimation approach is described in the EPA Air Pollution Control Cost Manual (U.S. EPA, 2017). These annualized costs are the costs to directly affected firms and facilities (or “private investment”), and thus are not true social costs. Detailed discussion of these costs, including all calculations and assumptions made in conducting estimates of total capital investment, annual O&M, and compliance testing/R&R costs, can be found in the technical memo produced for the proposed rule that can be found in the docket. The bank prime rate was 7.00 percent at the time of the analysis but has since risen to 8.00 percent. All cost figures are in 2022$.

3.5.1.1 Facility-Level Impacts of Hg Regulatory Options

Facility-level impacts of the proposed, less stringent, and more stringent regulatory alternatives for Hg are presented in Table 3-7, Table 3-8, and Table 3-9 below. Costs are presented at the facility level, the firm level, and the industry level. Annualized costs include annualized costs of compliance testing every 2.5 years and R&R.

The proposed standards for Hg set a numerical MACT-floor limit for Hg that applies to average indurating furnaces at a facility. The MACT-floor limit is based on the emissions from indurating furnaces at the Northshore and Tilden facilities; all other facilities are expected to require additional controls to meet the proposed limit (see Section 3.3.1). There is uncertainty associated with how each facility will achieve the necessary emissions reductions. The analysis presented in this EIA assumes that each facility will meet the Hg emissions limit by replacing their existing controls with a Venturi wet scrubber equipped with an activated carbon injection (ACI) system designed to control Hg. The costs of the system vary by the number of furnaces present at a facility and the exhaust gas flow rate of each furnace. For details, see the Technical Memo.

Table 3-7: Facility-Level Impacts of the Proposed Hg Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$42,000,000	$19,000,000	$23,000,000
	Minorca	$21,000,000	$8,500,000	$10,000,000
	Northshore	$0	$0	$170,000
	United	$13,000,000	$6,900,000	$8,200,000
	Tilden	$0	$0	$44,000
	Firm Total	$75,000,000	$34,000,000	$42,000,000
U.S. Steel	Keetac	$7,800,000	$4,900,000	$5,700,000
	Minntac	$6,800,000	$3,900,000	$4,600,000
	Firm Total	$15,000,000	$8,800,000	$10,000,000
Industry	Total	$90,000,000	$43,000,000	$52,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

The less stringent alternative standards considered for Hg apply the MACT-floor limit to each individual furnace at a facility. EPA projects this would require the Hibbing, United, and Minntac facilities to install additional controls relative to the proposed option to meet the standard. This would likely happen because the Hg emissions from a furnace depend on the Hg content of the iron ore processed in a furnace, which is a function of mine location and is not known in advance. If processing the iron ore in a particular location would sometimes violate the MACT-floor limit, a facility would need to control all furnaces to meet the limit at all times. This option increases compliance cost but leads to less Hg reduction. Applying the MACT floor limit to individual furnaces increases total capital investment by about $40 million and total annualized cost by about $19 million industry-wide relative to the proposed option.

Table 3-8: Facility-Level Impacts of the Less Stringent Alternative Hg Standards

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$59,000,000	$25,000,000	$31,000,000
	Minorca	$21,000,000	$8,500,000	$10,000,000
	Northshore	$0	$0	$170,000
	United	$18,000,000	$8,800,000	$11,000,000
	Tilden	$0	$0	$44,000
	Firm Total	$98,000,000	$43,000,000	$52,000,000
U.S. Steel	Keetac	$7,800,000	$4,900,000	$5,700,000
	Minntac	$0	$0	$13,000,000
	Firm Total	$31,000,000	$16,000,000	$19,000,000
Industry	Total	$130,000,000	$58,000,000	$71,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

The more stringent alternative standard considered for Hg is a 10 percent BTF limit to each individual furnace at a facility. EPA projects this would not require additional controls relative to the less stringent option, but would lead to higher compliance costs due to additional ACI requirements. Applying the BTF limit to each increases total capital investment by about $51 million and total annualized cost by about $25 million industry-wide.

Table 3-9: Facility-Level Impacts of the More Stringent Alternative Hg Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$60,000,000	$29,000,000	$32,000,000
	Minorca	$21,000,000	$9,500,000	$11,000,000
	Northshore	$0	$0	$170,000
	United	$18,000,000	$9,800,000	$11,000,000
	Tilden	$0	$0	$44,000
	Firm Total	$99,000,000	$48,000,000	$54,000,000
U.S. Steel	Keetac	$7,800,000	$5,200,000	$5,700,000
	Minntac	$24,000,000	$13,000,000	$14,000,000
	Firm Total	$32,000,000	$18,000,000	$20,000,000
Industry	Total	$130,000,000	$66,000,000	$73,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.5.1.2 Facility-Level of Acid Gas Regulatory Options

Facility-level impacts of the proposed and more stringent regulatory alternatives for acid gases are presented in Table 3-10 and Table 3-11 below. The less stringent alternative acid gas standard maintains the PM surrogate standard for acid gas emissions. This option maintains the status quo and does not require additional cost. Costs are presented at the facility level, the firm level, and the industry level. Annualized costs include annualized costs of compliance testing every 2.5 years and R&R.

The proposed standards for acid gas set a numerical MACT-floor limit for both HCl and HF that apply to each individual indurating furnace. EPA estimates that the Tilden facility would meet the limit by using DSI with hydrated lime in its dry ESP. All other facilities are expected to meet the limit without additional emission control. The annualized costs for the other six facilities include compliance testing and R&R associated with the new standards.

Table 3-10: Facility-Level Impacts of the Proposed Acid Gas Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$0	$0	$130,000
	Minorca	$0	$0	$42,000
	Northshore	$0	$0	$170,000
	United	$0	$0	$32,000
	Tilden	$1,100,000	$1,300,000	$1,400,000
	Firm Total	$1,100,000	$1,300,000	$1,800,000
U.S. Steel	Keetac	$0	$0	$11,000
	Minntac	$0	$0	$55,000
	Firm Total	$0	$0	$66,000
Industry	Total	$1,100,000	$1,300,000	$1,900,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

The more stringent alternative option for acid gases sets a beyond-the-floor (BTF) MACT-limit for both HCl and HF that is 30 percent more restrictive than the proposed MACT-floor limit that applies to each individual indurating furnace. This approach would require additional acid gas reductions from the Tilden facility. We assume Tilden would meet the stricter standard by using trona rather than hydrated lime as an absorbent to further control acid gas emissions, but would not require additional pollution controls.

Table 3-11: Facility-Level Impacts of the More Stringent Alternative Acid Gas Standards

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$0	$0	$130,000
	Minorca	$0	$0	$42,000
	Northshore	$0	$0	$170,000
	United	$0	$0	$32,000
	Tilden	$1,100,000	$1,800,000	$2,400,000
	Firm Total	$1,100,000	$1,800,000	$2,700,000
U.S. Steel	Keetac	$0	$0	$11,000
	Minntac	$0	$0	$55,000
	Firm Total	$0	$0	$66,000
Industry	Total	$1,100,000	$1,800,000	$2,800,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.5.1.3 Summary of Facility-Level Impacts

This section contains summary tables for each set of regulatory alternatives that contain impacts of the Hg and acid gas standards cumulatively. They are presented in Table 3-12, Table 3-13, and Table 3-14 below. The tables include sums of the values of the corresponding tables in the Section 3.5.1.1 and 3.5.1.2, but are included here for completeness and comparison. Costs are presented at the facility level, the firm level, and the industry level.

Table 3-12: Summary of Facility-Level Impacts of Proposed Hg and Acid Gas Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$42,000,000	$19,000,000	$23,000,000
	Minorca	$21,000,000	$8,500,000	$11,000,000
	Northshore	$0	$0	$340,000
	United	$13,000,000	$6,900,000	$8,200,000
	Tilden	$1,100,000	$1,300,000	$1,500,000
	Firm Total	$76,000,000	$36,000,000	$44,000,000
U.S. Steel	Keetac	$7,800,000	$4,900,000	$5,700,000
	Minntac	$6,800,000	$3,900,000	$4,700,000
	Firm Total	$15,000,000	$8,800,000	$10,000,000
Industry	Total	$91,000,000	$44,000,000	$54,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-13: Summary of Facility-Level Impacts of the Less Stringent Alternative Hg and Acid Gas Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$59,000,000	$25,000,000	$31,000,000
	Minorca	$21,000,000	$8,500,000	$10,000,000
	Northshore	$0	$0	$170,000
	United	$18,000,000	$8,800,000	$11,000,000
	Tilden	$0	$0	$44,000
	Firm Total	$98,000,000	$43,000,000	$52,000,000
U.S. Steel	Keetac	$7,800,000	$4,900,000	$5,700,000
	Minntac	$0	$0	$13,000,000
	Firm Total	$31,000,000	$16,000,000	$19,000,000
Industry	Total	$130,000,000	$58,000,000	$71,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-14: Summary of Facility-Level Impacts of the More Stringent Alternative Hg and Acid Gas Standards (2022$)

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Hibbing	$60,000,000	$29,000,000	$32,000,000
	Minorca	$21,000,000	$9,500,000	$11,000,000
	Northshore	$0	$0	$340,000
	United	$18,000,000	$9,800,000	$11,000,000
	Tilden	$1,100,000	$1,800,000	$2,400,000
	Firm Total	$100,000,000	$50,000,000	$56,000,000
U.S. Steel	Keetac	$7,800,000	$5,200,000	$5,700,000
	Minntac	$24,000,000	$13,000,000	$14,000,000
	Firm Total	$32,000,000	$18,000,000	$20,000,000
Industry	Total	$130,000,000	$68,000,000	$76,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.5.2 *Summary Cost Tables for the Proposed Regulatory Options*

This section presents summary cost tables for the proposed regulatory options. Table 3-15 presents total capital investment and various annualized costs for the proposed options for Hg and acid gases separately and cumulatively. The vast majority of projected total capital investment and total annualized cost occurs as a result of the proposed Hg requirements.

Table 3-15: Summary of Total Capital Investment and Annual Costs per Year of the Proposed Option by Pollutant (2022$)

	Hg	Acid Gases	Total
Total Capital Investment	$90,000,000	$1,100,000	$91,000,000
Annual O&M	$43,000,000	$1,300,000	$44,000,000
Annualized Capital	$8,500,000	$100,000	$8,600,000
Annualized Testing/R&R	$490,000	$470,000	$960,000
Total Annualized Cost	$52,000,000	$1,900,000	$54,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-16 presents estimated costs by year based on when costs are likely to be incurred. Although firms may spread capital investment across the three years prior to full implementation of the proposed standards, we conservatively assume that all capital investment occurs in the first year of full implementation to represent a highest-cost scenario. Compliance testing occurs initially and once every 2.5 years thereafter. Since compliance must occur within 3 years of the effective date of the proposed amendments, these costs are assumed to occur in 2027 (the first year of full implementation). Firms may spread these costs across the years between the effective date of the amendments and 2027. Table 3-17 presents total costs for each year discounted to 2023, along with the present-value (PV) and equivalent annualized value (EAV) over the analysis period, using both a 3 percent and 7 percent social discount rate. The EAV represents a flow of constant annual values that would yield a sum equivalent to the PV. The estimated present-value of compliance costs in 2023 is about $430 million ($51 million EAV) using a 3% social discount rate and about $330 million ($47 million EAV) using a 7% social discount rate from 2027-2036.

Table 3-16: Costs by Year for the Proposed Options (2022$)

Year	Capital	Annual O&M	Testing/R&R	Total
2027	$91,000,000	$44,000,000	$2,100,000	$140,000,000
2028	$0	$44,000,000	$25,000	$44,000,000
2029	$0	$44,000,000	$25,000	$44,000,000
2030	$0	$44,000,000	$25,000	$44,000,000
2031	$0	$44,000,000	$25,000	$44,000,000
2032	$0	$44,000,000	$2,100,000	$47,000,000
2033	$0	$44,000,000	$25,000	$44,000,000
2034	$0	$44,000,000	$25,000	$44,000,000
2035	$0	$44,000,000	$25,000	$44,000,000
2036	$0	$44,000,000	$25,000	$44,000,000

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-17: Present-Value, Equivalent Annualized Value, and Discounted Costs for Proposed Options, 2027-2036 (million 2022$)

Year	Discount Rate (Discounted to 2023)	
	3%	7%
2027	$120	$100
2028	$38	$32
2029	$37	$30
2030	$36	$28
2031	$35	$26
2032	$36	$25
2033	$33	$23
2034	$32	$21
2035	$31	$20
2036	$30	$18
PV	**$430**	**$330**
EAV	**$51**	**$47**

Note: Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.6 Uncertainties and Limitations

Throughout the EIA, we considered a number of sources of uncertainty, both quantitatively and qualitatively, regarding the costs and emissions impacts of the proposed NESHAP amendments. We summarize the key elements of our discussions of uncertainty here:

- **Projection methods and assumptions**: The number of facilities in operation is assumed to be constant over the course of the analysis period. This is a particular source of uncertainty with respect to the Empire taconite mine, which is currently idled long-term. If the Empire facility were to resume operation, that could increase the projected costs and emissions impacts of the proposed amendments. Further, costs and emissions impacts at other affected facilities could change as the indurating furnaces in operation are modified or replaced. Unexpected facility closure or idling affects the number of facilities subject to the proposed amendments. We also assume 100 percent compliance with these proposed rules and existing rules, starting from when the source becomes affected. If sources do not comply with these rules, at all or as written, the cost impacts and emission reductions may be overestimated. Additionally, new control technology may become available in the future at lower cost, and we are unable to predict exactly how industry will comply with the proposed rules in the future.

- **Years of analysis**: The years of the cost analysis are 2027, to represent the first-year facilities are fully compliant with the amendments to Subpart RRRRR, through 2036, to present 10 years of potential regulatory impacts, as discussed in Chapter 3. Extending the analysis beyond 2036 would introduce substantial and increasing uncertainties in the projected impacts of the proposed regulations.
- **Compliance Costs**: There is uncertainty associated with the costs required to install and operate the equipment necessary to meet the proposed emissions limits. There is also uncertainty associated with the exact controls a facility may install to comply with the requirements, and the interest rate they are able to obtain if financing capital purchases. There may be an opportunity cost associated with the installation of environmental controls (for purposes of mitigating the emission of pollutants) that is not reflected in the compliance costs included in Chapter 3. If environmental investment displaces investment in productive capital, the difference between the rate of return on the marginal investment (which is discretionary in nature) displaced by the mandatory environmental investment is a measure of the opportunity cost of the environmental requirement to the regulated entity. To the extent that any opportunity costs are not included in the control costs, the compliance costs presented above for this proposed action may be underestimated.

- **Emissions Reductions**: Baseline emissions and projected emissions reductions are based on AP-42 emissions factors, assumptions about current emissions controls, and facility stack testing. To the extent that any of these data or assumptions are unrepresentative or outdated, the emissions reductions associated with the proposed amendments could be over or underestimated.

4 ECONOMIC IMPACT ANALYSIS AND DISTRIBUTIONAL ASSESSMENTS

4.1 Introduction

The proposed amendments to the NESHAP for Taconite Iron Ore are projected to result in total capital investment greater than $90 million, total annualized costs greater than $50 million per year, and are likely to have downstream impacts on the steel manufacturing industry due to the use of iron ore as an essential input at integrated iron and steel facilities.

While the national-level impacts demonstrate the proposed action is likely to lead to substantial costs, the engineering cost analysis does not speak fully to potential economic and distributional impacts of the proposed amendments, which may be important consequences of the action. This section includes economic impact and distributional analyses directed toward complementing the engineering cost analysis and includes a partial equilibrium analysis of market impacts.

As discussed in Chapter 2, two ultimate parent companies collectively own the seven active taconite iron ore processing facilities: Cleveland-Cliffs Inc. (Hibbing, Minorca, Northshore, United, and Tilden) and U.S. Steel (Keetac and Minntac). Cleveland-Cliffs Inc. also owns the Empire facility, which is idled long-term and does not currently have plans to resume operations.

Cleveland-Cliffs and U.S. Steel each reported greater than $20 billion in revenue in 2021. Table 4-1 and Table 4-2 present total annualized cost and total capital investment relative to sales for each set of regulatory alternatives (for a breakdown of facility-level costs, see Section 3.5.1). As shown in the tables, both total annualized cost and total capital investment (which could potentially be incurred by each firm in a single year) are small compared to total revenue for each firm (less than 0.50 percent for the proposed option). The total annualized cost per sales for a company represents the maximum price increase in the affected product or service needed to completely recover the annualized costs imposed by the regulation. Based on this estimate, the maximum necessary price increase caused by the proposed regulation is small relative to the size of the industry.

Table 4-1: Total Annualized Cost-to-Sales Ratios for Taconite Facility Owners by Regulatory Alternative

Ultimate Parent Company	Regulatory Alternative	2021 Revenue (million 2022$)	Total Annualized Cost (million 2022$)	TAC-Sales Ratio
Cleveland-Cliffs Inc.	Less Stringent	$21,742	$52	0.24%
	Proposed		$44	0.20%
	More Stringent		$56	0.26%
U.S. Steel	Less Stringent	$21,562	$19	0.09%
	Proposed		$10	0.05%
	More Stringent		$20	0.09%

Table 4-2: Total Capital Investment-to-Sales Ratios for Taconite Facility Owners by Regulatory Alternative

Ultimate Parent Company	Regulatory Alternative	2021 Revenue (million 2022$)	Total Capital Investment (million 2022$)	TCI-to-Sales Ratio
Cleveland-Cliffs Inc.	Less Stringent	$21,742	$98	0.45%
	Proposed		$76	0.35%
	More Stringent		$100	0.46%
U.S. Steel	Less Stringent	$21,562	$31	0.14%
	Proposed		$15	0.07%
	More Stringent		$32	0.15%

However, as discussed in Chapter 2, taconite is primarily an input used to manufacture steel products, and both Cleveland-Cliffs Inc. and U.S. Steel are vertically integrated along the steel supply chain. Impacts caused by the regulation are likely to have secondary impacts in related sectors. The next section introduces a partial equilibrium economic model that analyzes the interaction of the taconite sector with the steel sector and attempts to evaluate how producers and consumers may react and respond to increased regulatory costs. For example, producers may choose to reduce output in response to increased taconite processing costs, reducing market supply. Reduced market supply of taconite pellets increases their price, which causes cost increases and reduced production in the steel sector. The costs may also be passed along to consumers through price increases, who may respond by reducing steel consumption. The purpose of the next section is to measure and track these effects as they are distributed across stakeholders in the economy.

To evaluate the impact of the proposed amendments on the iron ore and steel mill products markets, the EPA developed two national competitive partial equilibrium models (for taconite and steel mill products) to estimate the economic impacts on society resulting from the regulation. These models were originally used to analyze the impacts of the original NESHAP for Taconite Iron Ore, and the model and its description in this chapter are adapted from the original *Taconite Iron Ore NESHAP Economic Impact Analysis* (U.S. EPA, 2003b).

We assume that, within each industry, the commodities of interest are homogeneous (e.g., perfectly substitutable) and that the number of buyers and sellers is large enough that no individual buyer or seller has market power (i.e., influence on market prices). As a result of these conditions, producers and consumers take the market price as a given when making their production and consumption choices. As discussed in Chapter 2 and earlier in this chapter, there are only two firms in the United States producing taconite iron ore for sale. This is a departure from the assumptions of the model, and the extent to which this impacts the results of the model is uncertain. Even so, we expect this model provides a useful illustration of the linkages between the taconite and steel sectors and as such provides a guide to the broad magnitude of the impacts we can expect from the proposed regulation. We present the results for a single representative year (2019).

4.2 Modeling Approach

The EPA modeled the impacts of increased environmental control costs using two standard partial equilibrium models: one for taconite iron ore and one for steel mill products. We have linked these two partial equilibrium models by specifying the interactions between supply and demand for products in each market and solving for the changes in prices and quantities across both markets simultaneously. Explicitly modeling these interactions helps better characterize the distributional impacts on downstream iron and steel producers in the steel mill products market. The following sections discuss how supply and demand are characterized for each market.

The model is a static, two-sector model characterized by iso-elastic demand/supply for each sector and producer. The supply of taconite pellets and steel each come from domestic producers and imports. Demand for taconite pellets comes from domestic steel producers and exports, while demand for steel comes from domestic and foreign steel consumers. The supply of domestic taconite is characterized at the individual facility level. The domestic supply of steel is characterized by two representative domestic producers, each using a separate production process: one steel producer uses the blast furnace/basic oxygen furnace (BF/BOPF) process, and the other uses the electric arc furnace process. For background on each production process, see Chapter 2.

4.2.1 *Supply*

Market supply is composed of domestic production (d) and imports (m):

$$Q^S = q^{Sd} + q^{Sm}$$

The change in quantity supplied by each domestic taconite facility can be approximated as follows:

$$\Delta q^{Sdt} = q_0^{Sdt} \cdot \epsilon^{Sdt} \cdot \frac{\Delta p_t - c}{p_{t0}}$$

Where q_0^{Sdt} is the baseline quantity of taconite pellets, ϵ^{Sdt} is domestic supply elasticity of taconite pellets, $\Delta p_t - c$ is the change in the producer's net price, and p_{t0} is the baseline price of taconite pellets. The change in net price is composed of the change in the market price of taconite pellets resulting from the regulation (Δp_t) and the shift in the domestic supply function caused by the regulatory compliance cost per metric ton of pellets (c). Each domestic facility's supply shift is calculated by dividing estimated total annualized compliance cost by baseline output.

Domestic steel producers using the BF/BOPF process use taconite pellets as an input to production. Their supply decision can be approximated as:

$$\Delta q^{Sds} = q_0^{Sds} \cdot \epsilon^{Sds} \cdot \frac{\Delta p_s - \alpha \Delta p_t}{p_{s0}}$$

where q_0^{Sds} is the baseline quantity of BF/BOPF steel, ϵ^{Sds} is the elasticity of domestic steel supply, $\Delta p_s - \alpha \Delta p_t$ is the change in the producer's net price, and p_{s0} is the baseline price of steel. The parameter α represents the amount of taconite pellets per unit of steel output (calibrated to be 1.51 metric tons taconite pellets per metric ton steel from baseline data). The change in the net price of steel is composed of the change in the baseline price of steel resulting from the regulation and the shift in the domestic supply function of BF/BOPF steel resulting from the increase in the price of taconite pellets.

The change in quantity supplied by domestic EAF steel producers and foreign iron and steel producers can be approximated as follows:

$$\Delta q^{Su} = q_0^{Su} \cdot \epsilon^{Su} \cdot \frac{\Delta p}{p_0}$$

where q_0^{Su} is the relevant baseline output, ϵ^{Su} is the relevant supply elasticity, and p_0 is the relevant baseline price. These producers do not face increased environmental control costs resulting from regulation and do not use taconite as an input, so their net price change equals the change in the relevant market price. As a result, these producers increase output in response to higher prices.

4.2.2 *Demand*

Market demand is composed of domestic consumption (d) and exports (x):

$$Q^D = q^{Dd} + q^{Dx}$$

The change in quantity demanded by domestic and foreign consumers can be approximated as:

$$\Delta q^{Di} = q_0^{Di} \cdot \eta^{Di} \cdot \frac{\Delta p}{p_0}$$

where q_0^D is baseline consumption, η^D is the elasticity of demand of the respective consumer (*i*), Δp is the change in the relevant market price, and p_0 is the relevant baseline price.

4.2.3 *Equilibrium*

The new with-regulation equilibrium occurs where the change in total market supply equals the change in total market demand:

$$\Delta Q^S = \Delta Q^D$$

We use the model equations described above and a solver application from the GAMS software package to compute the price and quantity changes necessary to achieve equilibrium. The transition to the new equilibrium can be described as follows.

- Both markets begin in the baseline equilibrium.

- Taconite pellet producers receive a compliance cost shock from regulation, which shifts the supply curve for each taconite producer.
- The compliance cost shock shifts the taconite market supply curve and raises the price of taconite pellets.
- The higher price of taconite pellets propagates the compliance cost shock to BF/BOPF steel, which uses taconite pellets as an input. This shifts the supply curve for BF/BOPF steel.
- This shifts the steel products market supply curve and raises the price of steel products.
- The model solves for the equilibrium price changes that balance market supply and demand in both markets simultaneously.

4.2.4 *Baseline Data and Parameters*

Running the model requires selecting a baseline year, characterizing supply and demand in the baseline year for both markets, and selecting elasticity parameters for each producer/consumer. We selected 2019 as the baseline year for the analysis, as this was the most recent year of data available after excluding 2020 (which, as described in Chapter 2, is an outlier year for iron and steel markets due to the Covid-19 pandemic).

The baseline market data for 2019 is in Table 4-3 below. Baseline production for taconite pellets is characterized at the facility level, while baseline production of steel products is characterized at the production-process level. Data on all prices and quantities for taconite iron ore pellets and comes from the USGS Minerals Yearbook 2019 (Tuck, 2020a). The price of iron ore represents the average value reported at mines. Data on domestic production, imports, and exports of steel mill products also come from USGS Minerals Yearbook 2019 (Tuck, 2020b). We divide domestic steel mill production between the BF/BOPF and EAF production process based on the assumption that 70 percent of U.S. steel output in 2019 comes from EAF (Tuck, 2020b). The baseline price of steel mill products comes from historical price data for hot-rolled coil steel (the most common steel mill product) collected from www.focus-economics.com.[6] Elasticity parameters for each producer/consumer are in Table 4-4 below. Many of the

[6] https://www.focus-economics.com/commodities/base-metals/steel-usa. Accessed 1/13/2023.

elasticities have been carried over from the original NESHAP, but others have been updated based on the economic literature when possible. The model incorporates separate elasticities for BOPF and EAF produced steel, as EAF facilities are more responsive to price changes due to a more flexible cost structure (Mathiesen & Moestad, 2004). A brief discussion of the elasticity of supply and demand in the iron ore and steel mill products market can be found in Section 2.5.2.3.

Table 4-3: Baseline Price and Quantity Data Taconite Pellets and Steel Mill Products, 2019

Market	Domestic Production (million metric tons)	Imports (million metric tons)	Exports (million metric tons)	Price ($/metric ton)
Taconite Pellets[a]	**47.3**	**3.98**[a]	**11.4**[a]	**92.94**[a]
Hibbing	*7.6*			
Minorca	*2.8*			
Northshore	*5.3*			
United	*5.4*			
Tilden	*7.8*			
Keetac	*5.3*			
Minntac	*13.1*			
Steel Mill Products	**87.8**[b]	**25.3**[b]	**6.7**[b]	**603.52**[c]
BF/BOPF	*26.3*			
EAF	*61.5*			

[a] Tuck (2020a) *Iron Ore* [tables-only release]. USGS Minerals Yearbook 2019 (volume 1) – Metals and Minerals. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information. Accessed 1/30/2023.
[b] Tuck (2020b) *Iron and* Steel [tables-only release]. USGS Minerals Yearbook 2019 (volume 1) – Metals and Minerals. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information. Accessed 1/30/2023.
[c] https://www.focus-economics.com/commodities/base-metals/steel-usa. Accessed 1/30/2023.

Table 4-4: Elasticity Parameters for Taconite Pellets and Steel Mill Products

Market	Supply	Demand
Taconite Pellets		
Domestic	0.5[a]	derived demand
Foreign	1.08[b]	-0.92[b]
Steel Mill Products		
Domestic	0.7 (BF/BOPF), 1.2 (EAF)[c]	-0.59[b]
Foreign	10[d]	-1.25[b]

[a] Fisher, B. S., Beare, S., Matysek, A. L., & Fisher, A. (2015). The impacts of potential iron ore supply restrictions on producer country welfare. BAE Economics. Available at: http://www.baeconomics.com.au/wp-content/uploads/2015/08/Iron-Ore-Spatial-Equilibrium-Model-8Aug15.pdf.
[b] Environmental Protection Agency. (2003). Taconite iron ore NESHAP economic impact analysis. Environmental Protection Agency. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100D5QR.pdf.
[c] Mathiesen, L., & Maestad, O. (2004). Climate policy and the steel industry: Achieving global emission reductions by an incomplete climate agreement. The Energy Journal, 25, 91–114. Available at: https://doi.org/10.2307/41323359.

[d] Fetzer. J. J. (2005). A partial equilibrium approach to modeling vertical linkages in the U.S. flat rolled steel market. U.S. International Trade Commission. Office of Economics Working Paper No. 2005-01-A. Available at: https://www.usitc.gov/publications/332/ec200501a.pdf.

Compliance cost shocks for the proposed option for each facility are in Table 4-5 below. Cost shocks are presented in 2019 dollars to match the dollar-year of the baseline prices and the year of the baseline data. Compliance costs per metric ton are highest at Hibbing and Minorca (over 2.9 percent of the baseline price) and lowest at Northshore and Tilden, which are the two facilities that are not expected to require additional controls to meet the proposed MACT-floor limit for Hg emissions.

Table 4-5: Facility-Level Compliance Cost Shocks for Proposed Options, ($2019)

Facility	$/Metric Ton	% of Baseline Price
Hibbing	2.70	2.90%
Minorca	3.34	3.59%
Northshore	0.06	0.06%
United	1.35	1.46%
Tilden	0.17	0.18%
Keetac	0.95	1.03%
Minntac	0.32	0.34%

4.2.5 *Economic Impact Results*

4.2.5.1 Market-Level Results

Table 4-6 presents projected approximate price and quantity changes in the taconite pellet and still mill product market under the proposed regulatory options, using 2019 as the baseline year. These results illustrate a variety of dynamics. First, note that while the prices of both taconite pellets and steel mill products increase, the increase in the price of steel mill products is very small relative to the increase in the price of taconite pellets. This is for three reasons. First, part of the decrease in quantity supplied of domestic taconite pellets is offset by an increase in imports of taconite pellets. Second, the decrease in BF/BOPF steel output is partially offset by an increase in EAF steel, which does not use taconite as an input and has gained a relative cost advantage. Third, the compliance cost shock is only propagated to the BF/BOPF production process, which makes up only 30 percent of steel production in the baseline year. Since it is expected that since the EAF process will likely continue to grow its share of U.S. steel production in coming years, this will serve to blunt the impact of the regulation on U.S. steel prices and production. Next, note that, because compliance costs are unevenly distributed over facilities, the regulation has the effect of shifting taconite output between facilities. Northshore, Tilden, and Minntac actually increase quantity due to the regulation, because the equilibrium price of taconite pellets increases more than compliance cost per metric ton at these facilities. Hibbing, Minorca, United, and Keetac experience declines in production. Table 4-7 and Table 4-8 show analogous results for the less stringent and more stringent alternative regulatory options for comparison.

Table 4-6: Projected Percentage Changes in Prices and Quantities of Taconite Pellets and Steel Mill Products under the Proposed Options

Market		Domestic Production	Imports	Exports	Price
Iron Ore		**-0.26%**	**0.62%**	**-0.53%**	**0.58%**
	Hibbing	*-1.16%*			
	Minorca	*-1.51%*			
	Northshore	*0.26%*			
	United	*-0.44%*			
	Tilden	*0.20%*			
	Keetac	*-0.22%*			
	Minntac	*0.12%*			
Steel Mill Products		**-0.02%**	**0.06%**	**-0.01%**	**0.01%**
	BF/BOPF	*-0.09%*			
	EAF	*0.01%*			

Table 4-7: Projected Percentage Changes in Prices and Quantities of Taconite Pellets and Steel Mill Products under the Less Stringent Alternative Options

Market		Domestic Production	Imports	Exports	Price
Iron Ore		**-0.34%**	**0.82%**	**-0.70%**	**0.76%**
	Hibbing	*-1.57%*			
	Minorca	*-1.41%*			
	Northshore	*0.36%*			
	United	*-0.55%*			
	Tilden	*0.38%*			
	Keetac	*-0.13%*			
	Minntac	*-0.09%*			
Steel Mill Products		**-0.03%**	**0.08%**	**-0.01%**	**0.01%**
	BF/BOPF	*-0.12%*			
	EAF	*0.01%*			

Table 4-8: Projected Percentage Changes in Prices and Quantities of Taconite Pellets and Steel Mill Products under the More Stringent Alternative Options

Market		Domestic Production	Imports	Exports	Price
Iron Ore		**-0.36%**	**0.88%**	**-0.75%**	**0.81%**
	Hibbing	*-1.61%*			
	Minorca	*-1.41%*			
	Northshore	*0.38%*			
	United	*-0.56%*			
	Tilden	*0.26%*			
	Keetac	*-0.11%*			
	Minntac	*-0.11%*			
Steel Mill Products		**-0.03%**	**0.08%**	**-0.01%**	**0.01%**
	BF/BOPF	*-0.13%*			
	EAF	*0.01%*			

4.2.5.2 *Welfare Change Estimates*[7,8]

Table 4-9 presents the projected welfare impacts under the proposed options. Welfare impacts are presented in terms of consumer and producer surplus. Consumer and producer surplus are standard measures of economic welfare which relate the difference between willingness to pay (or sell, in the case of producers) for a product or service and its price. Note that consumer surplus only applies to domestic and foreign consumers of steel mill products, since the consumers of taconite pellets are the producers of BF/BOPF steel, and their welfare change is measured by their producer surplus change. Note that these welfare impacts do not include benefits of pollution abatement or the costs of secondary emission impacts from increased electricity from operating environmental controls.

Consumers of U.S. steel mill products are unambiguously worse off (excluding the beneficial impacts of pollution abatement), as both foreign and domestic consumers of steel pay a higher price. BF/BOPF steel producers are worse off due reduced output, but their losses are partially offset by gains to EAF steel producers who increase output and receive a higher price for steel. Finally, note that some taconite facilities gain and some lose due to the regulation. Both Cleveland-Cliffs Inc. (Hibbing, Minorca, Northshore, United, and Tilden) and U.S. Steel (Keetac and Minntac) facilities are worse off on net. The model projects total welfare losses of about $51 million (2019$). For context, the U.S. steel market was worth approximately $9.4 billion in 2019[9], so the projected welfare losses under the proposed options are about 0.6 percent of the entire U.S. steel market. Table 4-10 and Table 4-11 present projected welfare impacts under the less and more stringent alternative regulatory options.

[7] Changes in consumer surplus are estimated from changes in prices and quantities using the following linear approximation formula: $\Delta CS = -(\Delta P * Q_{new}) + .5 * \Delta P * \Delta Q$.

[8] Changes in producer surplus are estimated from changes in prices and quantities using the following linear approximation formula: $\Delta PS = (\Delta P) * Q_{new} - .5 * \Delta P * \Delta Q$, where ΔP represents the net price to the producer.

[9] https://www.grandviewresearch.com/industry-analysis/us-steel-merchant-rebar-market#:~:text=Report%20Overview,5.2%25%20from%202020%20to%202027. Accessed 1/13/2023.

Table 4-9: Summary of Projected Consumer and Producer Surplus Changes under the Proposed Options

Change in Producer Surplus		Change in Consumer Surplus	
Producers	**Million 2019$**	**Market**	**Million 2019$**
Iron Ore	**-$22.38**	**Domestic**	**-$3.83**
Hibbing	*-$16.31*	**Foreign**	**-$0.24**
Minorca	*-$7.78*		
Northshore	*$2.55*		
United	*-$4.40*		
Tilden	*$2.88*		
Keetac	*-$2.20*		
Minntac	*$2.88*		
Steel Mill Products	**-$18.24**		
BF/BOPF	*-$20.45*		
EAF	*$2.21*		
Change in Producer Surplus	**-$40.61**		
Change in Consumer Surplus	**-$4.07**		
Change in Total Welfare	**-$44.69**		

Table 4-10: Summary of Projected Consumer and Producer Surplus Changes under the Less Stringent Alternative Options

Change in Producer Surplus		Change in Consumer Surplus	
Producers	**Million 2019$**	**Market**	**Million 2019$**
Iron Ore	**-$29.33**	**Domestic**	**-$5.02**
Hibbing	*-$21.98*	**Foreign**	**-$0.32**
Minorca	*-$7.28*		
Northshore	*$3.59*		
United	*-$5.55*		
Tilden	*$5.46*		
Keetac	*-$1.31*		
Minntac	*-$2.26*		
Steel Mill Products	**-$23.92**		
BOPF	*-$26.83*		
EAF	*$2.90*		
Change in Producer Surplus	**-$53.25**		
Change in Consumer Surplus	**-$5.34**		
Change in Total Welfare	**-$58.59**		

Table 4-11: Summary of Projected Consumer and Producer Surplus Changes under the More Stringent Alternative Options

Change in Producer Surplus			Change in Consumer Surplus	
Producers		**Million 2019$**	**Market**	**Million 2019$**
Iron Ore		**-$31.53**	**Domestic**	**-$5.40**
	Hibbing	*-$22.50*	**Foreign**	**-$0.34**
	Minorca	*-$7.27*		
	Northshore	*$3.72*		
	United	*-$5.60*		
	Tilden	*$3.78*		
	Keetac	*-$1.09*		
	Minntac	*-$2.57*		
Steel Mill Products		**-$25.71**		
	BOPF	*-$28.83*		
	EAF	*$3.12*		
Change in Producer Surplus		**-$57.24**		
Change in Consumer Surplus		**-$5.74**		
Change in Total Welfare		**-$62.98**		

4.2.5.3 Limitations

Ultimately, the regulatory program will increase the costs of supplying taconite pellets to U.S. steel producers, and the model is designed to evaluate behavioral responses to this change in costs within a market equilibrium setting. However, the results should be viewed with the following limitations in mind. First, the national competitive market assumption is clearly very strong because there is a geographic relationship between taconite facilities and integrated iron and steel mills that impacts the distribution of taconite pellets to steel producers. Regional price and quantity impacts could be different from the average impacts reported below if local market structures, production and shipping costs, or demand conditions are substantially different from those used in this analysis. Second, abstracts away from facility ownership and models all taconite facilities as individual producers. Therefore, it does not address potential strategic decisions and pricing strategies by Cleveland-Cliffs and U.S. Steel in response to the regulation allowed by their potential market power and vertically integrated structure. Although directly modeling the competitive conditions of the taconite market and vertical relationships between taconite and steel facilities is possible, this type of model requires substantial amounts of detailed data for individual steel facilities and a level of effort beyond the scope of this analysis.

4.3 Employment Impact Analysis

This section presents a qualitative overview of the various ways that environmental regulation can affect employment. Employment impacts of environmental regulations are generally composed of a mix of potential declines and gains in different areas of the economy over time. Regulatory employment impacts can vary across occupations, regions, and industries; by labor and product demand and supply elasticities; and in response to other labor market conditions. Isolating such impacts is a challenge, as they are difficult to disentangle from employment impacts caused by a wide variety of ongoing, concurrent economic changes. The EPA continues to explore the relevant theoretical and empirical literature and to seek public comments in order to ensure that the way the EPA characterizes the employment effects of its regulations is reasonable and informative.

Environmental regulation "typically affects the distribution of employment among industries rather than the general employment level" (Arrow, et al., 1996). Even if impacts are small after long-run market adjustments to full employment, many regulatory actions have transitional effects in the short run (Office of Management and Budget, 2015). These movements of workers in and out of jobs in response to environmental regulation are potentially important and of interest to policymakers. Transitional job losses have consequences for workers that operate in declining industries or occupations, have limited capacity to migrate, or reside in communities or regions with high unemployment rates.

As indicated by the market analysis presented in Section 4.2, the proposed requirements are likely to cause only small shifts in iron and steel consumption and prices. As a result, demand for labor employed in taconite pellet and steel distribution activities and associated industries, is unlikely to see large changes. However, these industries might experience adjustments as there may be increases in compliance-related labor requirements such as labor associated with the manufacture, installation, and operation of pollution control equipment such as new or upgraded Venturi wet scrubbers and ACI systems and emissions monitors. In addition, there may be changes in employment due to effects on output from directly regulated sectors and sectors that consume iron and steel. If steel prices increase sufficiently as a result of this action, then revenues of firms directly regulated and those in steel-consuming sectors may fall and their employment may potentially decline (though such changes should likely be small in light of the estimated change in output price mentioned above). For this proposal, we do not have the data and analysis available to quantify potential labor impacts, although we expect those impacts to be relatively small.

4.4 Small Business Impacts

To determine the possible impacts of the proposed NESHAP amendments on small businesses, parent companies producing taconite are categorized as small or large using the Small Business Administration's (SBA's) general size standards definitions. For NAICS 21221, these guidelines indicate a small business employs 750 or fewer workers.[10] Only two ultimate parent companies, Cleveland-Cliffs Inc. and U.S. Steel, own taconite facilities. Based on the SBA definition and the company employment shown in Table 2-8, this industry has no small businesses.

[10] U.S. Small Business Administration, Table of Standards, Effective December 19, 2022. Available at: https://www.sba.gov/document/support--table-size-standards. Accessed January 17, 2023.

5 REFERENCES

- Arrow, K. J., Cropper, M. L., Eads, G. C., Hahn, R. J., Lave, L. B., Noll, R. J., . . . Stavins, R. N. (1996). *Benefit-Cost Analysis in Environmental, Health, and Saftey Regulation: A Statement of Principles.* American Enterprise Institute Press.
- Cheminfo Services Inc. (2019). *Economic Assessment of the Integrated Steel Industry: Final Report.* Available at: https://canadiansteel.ca/files/resources/Final-Report-Economic-Assessment-of-the-Integrated-Steel-Industry.pdf: Submitted to: Canadian Steel Producers Association.
- Engström, K., & Esbensen, K. H. (2018). Evaluation of sampling systems in iron ore concentrating and pelletizing processes – Quantification of total sampling error (TSE) vs. process variation. *Minerals Engineering, 116*, 203–208. https://doi.org/10.1016/j.mineng.2017.07.008.
- Fernandez, V. (2018). Price and income elasticity of demand for mineral commodities. Resources Policy, 59, 160–183. Available at: https://doi.org/10.1016/j.resourpol.2018.06.013.
- Fetzer. J. J. (2005). A partial equilibrium approach to modeling vertical linkages in the U.S. flat rolled steel market. U.S. International Trade Commission. Office of Economics Working Paper No. 2005-01-A. Available at: https://www.usitc.gov/publications/332/ec200501a.pdf.
- Fisher, B. S., Beare, S., Matysek, A. L., & Fisher, A. (2015). The impacts of potential iron ore supply restrictions on producer country welfare. BAE Economics. Available at: http://www.baeconomics.com.au/wp-content/uploads/2015/08/Iron-Ore-Spatial-Equilibrium-Model-8Aug15.pdf.
- Germeshausen, R., Panke, T., & Wertzel, H. (2015). Investigating the Influence of Firm Characteristics on the Ability to Exercise Market Power: A Stochastic Frontier Approach with an Application to the Iron Ore Market. *ZEW Centre for European Economic Research Discussion Paper No. 14-105*, http://dx.doi.org/10.2139/ssrn.2551754.
- IEA. (2020). *Iron and Steel Technology Roadmap: Towards more sustainable steelmaking.* Paris, France: OECD Publishing, https://doi.org/10.1787/3dcc2a1b-en.
- Kordazadeh, E., Campos, F., Struber, G., & Schwalm, T. (2017). Contributions to the Technology Comparison Between Straight Grate and Grate-Kiln. *Simpósio Brasileiro de Aglomeração de Minérios*, 222-236.
- Kublbock, K., Troster, B., & Eigner, M. (2022). Hard Facts and Environmental Impacts: An Overview of the Global Iron and Steel Sector. *OFSE Briefing Paper, No. 33. Austrian Foundation for Development Research, Vienna*, https://www.oefse.at/publikationen/briefing-papers/detail-briefing-paper/publication/show/ Publication/hard-facts-and-environmental-impacts.

- Mathiesen, L., & Moestad, O. (2004). Climate Policy and the Steel Industry: Achieving Global Emissions Reductions by an Incomplete Climate Agreement. *The Energy Journal*, Vol. 25, No. 4, 91-114.
- Minnesota Department of Revenue. (2022). *Mining Tax Guide.* Available at: https://www.revenue.state.mn.us/sites/default/files/2022-10/2022_mining_guide_0.pdf.
- OECD. (2021). *Latest Developments in Steelmaking Capacity.* Available at: https://www.oecd.org/industry/ind/latest-developments-in-steelmaking-capacity-2021.pdf.
- Office of Management and Budget. (2015). *2015 Report to Congress on the Benefits and Costs of Federal Regulations and Agency Compliance with the Unfunded Mandates Reform Act.* U.S. Office of Management and Budget, Office of Information and Regulatory Affairs.
- Oreskovich, J. A., Patelke, M. M., & Zanko, L. M. (2007). *Documenting the Historical Use of Taconite Byproducts as Construction Aggregates in Minnesota -- A GIS-based Compilation of Applications, Locations, Test Data, and Related Construction Information.* Natural Resources Research Institute, University of Minnesota Duluth, Available at: https://conservancy.umn.edu/bitstream/handle/11299/187156/TR-2007-22.pdf?sequence=1&isAllowed=y.
- Putney, D. (2023a). *Emissions Data Collected in 2022 for Indurating Furnaces Located at Taconite Iron Ore Processing Plants.* U.S. EPA, Office of Air Quality Planning and Standards.
- Putney, D. (2023c). *Development of Impacts for the Proposed Amendments to the NESHAP for Taconite Iron Ore Processing.* U.S. EPA, Office of Air Quality Planning and Standards.
- Tuck, C. C. (2019). *Iron Ore.* USGS Minerals Yearbook 2018. Available at: https://pubs.usgs.gov/myb/vol1/2018/myb1-2018-iron-ore.pdf.
- Tuck (2020a) *Iron Ore* [tables-only release]. USGS Minerals Yearbook 2019 (volume 1) – Metals and Minerals. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.
- Tuck (2020b) *Iron and* Steel [tables-only release]. USGS Minerals Yearbook 2019 (volume 1) – Metals and Minerals. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.
- Tuck, C. C. (2022a). *Iron Ore.* USGS Minerals Yearbook 2020. https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.
- Tuck, C. C. (2022b). *Iron Ore.* USGS Mineral Commodities Summary 2021. Available at: https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-iron-ore.pdf.
- Tuck, C. C. (2022c). *Iron Ore.* USGS Mineral Commodities Summary 2022. Available at: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-iron-ore.pdf.

- Tuck, C. C. (2022d). *Iron and Steel.* USGS Mineral Commodity Summaries 2022. Available at: https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-iron-steel.pdf.
- U.S. EPA. (2003a). *National Emissions Standards for Hazardous Air Pollution for Taconite Iron Ore Processing, Proposed Rule.* Office of Air Quality Planning and Standards, https://www.regulations.gov/document/EPA-HQ-OAR-2002-0039-0001.
- U.S. EPA. (2003b). *Taconite Iron Ore NESHAP Economic Impact Analysis.* Office of Air Quality Planning and Standards, https://www.epa.gov/sites/default/files/2020-07/documents/taconite_eia_neshap_final_08-2003.pdf.
- U.S. EPA. (2017). *EPA Air Pollution Control Cost Manual.* Office of Air Quality Planning and Standards, available at: https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution.
- USGS. (2019). *USGS Minerals Yearbook 2019, volume 1, Metals and Minerals.* Available at: https://www.usgs.gov/centers/national-minerals-information-center/minerals-yearbook-metals-and-minerals.
- World Steel Association. (2022). *2022 World steel in Figures.* Available at: https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2022-1.pdf.
- Zhu, Z. (2012). Identifying supply and demand elasticities of iron ore. Duke University, Durham, NC. Available at: https://sites.duke.edu/econhonors/files/2013/09/thesis_final_zhirui_zhuv21.pdf.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Health and Environmental Impacts Division Research Triangle Park, NC	Publication No. EPA-452/R-23-003 April 2023