Regulatory Impact Analysis for the Final National Emission Standards for Hazardous Air Pollutants: Integrated Iron and Steel Manufacturing Facilities Technology Review

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Regulatory Impact Analysis for the Final National Emission Standards for Hazardous Air Pollutants: Integrated Iron and Steel Manufacturing Facilities Technology Review

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).

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1 EXECUTIVE SUMMARY

1.1 Introduction

The U.S. Environmental Protection Agency (EPA) is finalizing amendments to the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Integrated Iron and Steel (II&S) Manufacturing Facilities (40 CFR Part 63, Subpart FFFFF), as required by the Clean Air Act (CAA). The II&S source category produces steel from iron ore pellets, coke, metal scrap and other raw materials using furnaces and other processes. The EPA is finalizing this rule to complete the technology review that was originally promulgated on July 13, 2020, and to address regulatory gaps in the NESHAP for II&S. This document presents the regulatory impact analysis (RIA) for this final rule.

To complete the required technology review, EPA is finalizing standards to address fugitive emissions from five unmeasured fugitive or intermittent particulate (UFIP) sources, referred to as "fugitive" sources: Bell Leaks, Unplanned Bleeder Valve Openings, Planned Bleeder Valve Openings, Slag Pits, and Beaching. Also, we are finalizing standards for carbonyl sulfide (COS), carbon disulfide (CS_2), mercury (Hg), hydrochloric acid (HCl), and hydrogen fluoride (HF) from sinter plants. In addition, we are finalizing standards for total hydrocarbons (THC), HCl, and dioxins/furans (D/F) from blast furnaces (BFs) and basic oxygen process furnaces (BOPFs). As part of an update to the technology review under 112(d)(6), we are finalizing to: add specific work practices for BOPF shop fugitives; and add D/F standards for sinter plants. Also under 112(d)(6), we are finalizing fenceline monitoring for chromium (Cr) including a work practice action level for Cr; if a monitor exceeds that level, the facility must conduct a root cause analysis and take corrective action to lower emissions.

In accordance with E.O. 12866 (as amended by E.O. 14094) and 13563, the guidelines of OMB Circular A-4 and EPA's *Guidelines for Preparing Economic Analyses* (U.S. EPA, 2016), the RIA analyzes the benefits and costs associated with the projected emissions reductions under the final requirements, a less stringent set of alternative requirements, and a more stringent set of alternative requirements to inform the EPA and the public about these projected impacts. The benefits and costs of the final rule and regulatory alternatives are presented for the 2026 to 2035 time period.

1.1.1 *Legal Basis for this Rulemaking*

Section 112 of the CAA provides the legal authority for this final rule. Section 112 of the CAA establishes a two-stage process to develop standards for emissions of HAP from new and existing stationary sources in various industries or sectors of the economy (*i.e.*, source categories). Generally, the first stage involves establishing technology-based standards and the second stage involves assessing whether additional standards are needed to address any remaining risk associated with HAP emissions from the source category. This second stage is referred to as the "residual risk review." In addition to the residual risk review, the CAA requires the EPA to review standards set under CAA section 112 every eight years and revise them as necessary, taking into account any "developments in practices, processes, or control technologies." This review is commonly referred to as the "technology review".

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 HAP listed in CAA section 112(b). Sources of HAP emissions are either major sources or area sources depending on the amount of HAP the source has the potential to emit.[1]

Major sources are required to meet the levels of reduction achieved in practice by the best-performing similar sources. CAA section 112(d)(2) states that the technology-based NESHAP must reflect the maximum degree of HAP emissions reduction achievable after considering cost, energy requirements, and non-air quality health and environmental impacts. These standards are commonly referred to as maximum achievable control technology (MACT) standards. MACT standards are based on emissions levels that are already being achieved by the best-controlled and lowest-emitting existing sources in a source category or subcategory. CAA section 112(d)(3) establishes a minimum stringency level for MACT standards, known as the MACT "floor." For area sources, CAA section 112(d)(5) gives the EPA discretion to set standards based on generally available control technologies or management practices (GACT) in lieu of MACT standards. In certain instances, CAA section 112(h) states that the EPA may set work practice standards in lieu of numerical emission standards.

1 "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."

The EPA must also consider control options that are more stringent than the MACT floor. Standards more stringent than the floor are commonly referred to as beyond-the-floor (BTF) standards. CAA section 112(d)(2) requires the EPA to determine whether the more stringent standards are achievable after considering the cost of achieving such standards, any non-air-quality health and environmental impacts, and the energy requirements of additional control.

For major sources and any area source categories subject to MACT standards, the second stage in the standard-setting process focuses on identifying and addressing any remaining (*i.e.*, "residual") risk pursuant to CAA section 112(f) and concurrently conducting a technology review pursuant to CAA section 112(d)(6). The EPA is required under CAA section 112(f)(2) to evaluate residual risk within eight years after promulgating a NESHAP to determine whether risks are acceptable and whether additional standards beyond the MACT standards are needed to provide an ample margin of safety to protect public health or prevent adverse environmental effects.[2] For area sources subject to GACT standards, there is no requirement to address residual risk, but technology reviews are required. Technology reviews assess developments in practices, processes, or control technologies and revise the standards as necessary without regard to risk, considering factors like cost and cost-effectiveness. The EPA is required to conduct a technology review every eight years after a NESHAP is promulgated. Thus, the first review after a NESHAP is promulgated is a residual risk and technology review (RTR) and the subsequent reviews are just technology reviews.

The EPA is also required to address regulatory gaps (*i.e.*, "gap-filling") when conducting NESHAP reviews, meaning it must establish missing standards for listed HAP that are known to be emitted from the source category. (*Louisiana Environmental Action Network v. EPA*, 955 F.3d 1088 (D.C. Cir. 2020) (*LEAN*)). 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)(4) or (h).

2 If risks are unacceptable, the EPA must determine the emissions standards necessary to reduce risk to an acceptable level without considering costs. In the second step of the approach, the EPA considers whether the emissions standards provide an ample margin of safety to protect public health in consideration of all health information as well as other relevant factors, including costs and economic impacts, technological feasibility, and other factors relevant to each particular decision.

1.1.2 *Regulatory Background*

II&S manufacturing facilities produce finished steel from iron ore using a process consisting mainly of a blast furnace (BF), a basic oxygen process furnace (BOPF), and in some cases sinter production. The blast furnace combines sinter, taconite iron ore pellets, coke, and limestone and creates a chemical reaction that produces molten iron and slag (a by-product consisting of lime, silicates, and aluminates). The iron is combined with scrap steel in the basic oxygen furnace to produce molten steel and slag. The slag is separated from the steel, which is then poured into a ladle for casting. Sinter plants recover the iron-bearing materials from BF and BOPF waste products for use in the blast furnace, and also produce limestone and dolomite for use in the blast furnace.

II&S facilities also include several ancillary processes, such as hot metal transfer, desulfurization, slag-skimming, and ladle metallurgy, but blast furnaces, basic oxygen furnaces, and sinter plants are the primary sources of HAP and particulate matter (PM) emissions from the source category. There are eight active II&S facilities in the United States, and three include sinter plants.

The EPA final the NESHAP for II&S facilities in 2003 under CAA section 112(d). The standards address emissions of HAP from new and existing sinter plants, blast furnaces, and basic oxygen process furnace (BOPF) shops using PM and opacity limits as surrogates for particulate HAP. Sinter plants also need to meet volatile organic compound (VOC) emission limits or limit oil content in sinter feed. The EPA amended the NESHAP in 2006 to add a new compliance option, revise emission limitations, reduce the frequency of repeat performance tests for certain emission units, add corrective action requirements, and clarify monitoring, recordkeeping, and reporting requirements.

In 2020, the EPA final the RTR for the source category. The 2020 RTR determined that risks from the source category were acceptable and provide an ample margin of safety to protect public health. The RTR did not identify cost-effective technology-based developments that would further reduce HAP emissions beyond the original NESHAP. The EPA, however, took final action to establish a new requirement to limit mercury (Hg) emissions from scrap metal used in steel operations. The EPA also final amendments to clarify that the standards are applicable during periods of startup, shutdown, and malfunction and require electronic reporting of performance test results, notifications of compliance status, and semi-annual reports. The final 2020 amendments also revised several monitoring requirements to increase flexibility.

1.1.3 *Final Requirements*

The final requirements are discussed briefly below. These include standards for currently regulated and unregulated fugitive sources, dioxins/furans and polycyclic aromatic hydrocarbons (PAH) from sinter plants, fenceline monitoring, and other standards to address current regulatory gaps. Each regulated emissions source is discussed in more detail in Section 3.2.

1.1.3.1 Currently Unregulated Fugitive or Intermittent Particulate Sources

EPA is finalizing standards to regulate five currently unregulated fugitive or intermittent particulate (UFIP) emissions sources: BF unplanned bleeder valve openings, BF planned bleeder valve openings, BF and BOPF slag processing, handling, and storage, BF bell leaks, and beaching of iron from BFs. For BF unplanned bleeder valve openings, EPA is finalizing specific work practice standards to limit the likelihood of slips that can cause these openings. For BF planned bleeder valve openings, EPA is finalizing an 8 percent opacity limit. EPA is finalizing an opacity limit for BF and BOPF slag processing, handling, and storage of 10 percent. For BF bell leaks, EPA is finalizing work practices and a 10 percent opacity action level. Finally, EPA is finalizing a MACT floor limit for fugitive emissions from the beaching of iron from BFs along with work practices to meet the limit.

1.1.3.2 Currently Regulated Fugitive Sources

EPA is finalizing updated requirements for one currently regulated source: basic oxygen process furnace (BOPF) shop fugitive emissions. Currently, fugitive emissions from both BOPF shop and BF casthouses are covered by a 20 percent opacity limit.

For BOPF shop fugitive emissions, EPA is finalizing specific work practices (such as optimizing the positioning of collection hoods and using higher draft velocities to capture more fugitives) but is not finalizing changes to the opacity limit. BOPF shop fugitives are likely the largest contributor of hexavalent chromium (Cr^{+6}) emissions at II&S facility fencelines, so facilities may need to install better fugitive capture systems to meet the fenceline action level for Cr^{+6} (discussed below in Section **Error! Reference source not found.**). For BF casthouse fugitive emissions, EPA is not finalizing changes to the opacity limit or specific work practices to meet the current opacity limit.

1.1.3.3 *Dioxins/Furans (D/F) and Polycyclic Aromatic Hydrocarbons (PAH) from Sinter Plants*

EPA is finalizing a limit based on technology review for D/F and PAH from sinter plant windboxes. There are currently no specific requirements for these pollutants, but the current VOC and oil content limits act as a surrogate standard for these HAP. Three II&S facilities have on-site sinter plants. These plants currently control windbox emissions using a baghouse, Venturi scrubber, or a baghouse in combination with a dry scrubber. EPA anticipates that all three affected facilities could meet this limit by installing an activated carbon injection system to complement existing windbox controls.

1.1.3.4 *Fenceline Monitoring*

EPA is finalizing a fenceline monitoring requirement pursuant to CAA section 112(d)(6). The fenceline monitoring requirement incudes a work practice action level for Cr. If a monitor at a facility exceeds the action level for Cr, the facility must do a root-cause analysis and take corrective action to lower Cr emissions. Based on current analyses, BOPF shop fugitive emissions are likely the largest contributor of Cr at II&S facility fencelines. EPA is also finalizing a sunset provision in the fenceline monitoring requirements: if facilities remain below half the action level (0.05 ug/m^3) for two full years, they can terminate the fenceline monitoring as long as they continue to comply with all other rule requirements.

1.1.3.5 *Other Regulatory Gaps*

EPA has also identified five unregulated HAP from sinter plants (CS_2, COS, HCl, HF, and Hg) and two unregulated HAP from blast furnaces (HCl and total hydrocarbons (THC)), and three unregulated HAP from basic oxygen furnaces and blast furnace stoves (HCl, THC, and D/F). EPA is finalizing MACT floor limits for COS and HCl from sinter plants, HCl and THC from blast furnaces and blast furnace stoves, and HCl, THC, and D/F from basic oxygen furnaces. EPA anticipates II&S facilities can meet the limits without installing additional controls. The only expected costs from these final standards, excluding Hg, are from additional compliance testing and monitoring, recordkeeping, and reporting requirements. For Hg, EPA is finalizing BTF limits that reflect the addition of ACI controls to the sinter plants. CS_2 emissions are being addressed through setting a limit for COS, HF emissions are being addressed through setting a limit for HCl, and D/F emissions from blast furnace stoves are being addressed through setting a limit for THC from blast furnace stoves.

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 steel. If the process of using a blast furnace and basic oxygen furnace to smelt iron and then manufacture steel 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 steel mill products may fail to incorporate the full opportunity cost to society of consuming them. 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 Results for the Final Rulemaking

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 RIA, we present results for the final amendments to the NESHAP for II&S manufacturing facilities relative to a world without the final amendments. The final amendments set standards for five currently unregulated fugitive emissions sources, revise standards for one currently regulated source of fugitive emissions, and set numerical limits for D/F and PAH from sinter plants. EPA is also finalizing fenceline monitoring requirements and setting MACT floor limits for four currently unregulated HAP (two from sinter plants, two from BF/BF stoves, and three from BOPF) and a BTF limit for Hg from sinter plants.

Throughout this document, the EPA focuses the analysis on the final 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 alternative regulatory option as compared to our final option in adherence to OMB Circular A-4. The results of this analysis are presented alongside analysis of the final option in Chapter 3.

1.2.2 *Methodology*

The impacts analysis summarized in this RIA reflects a nationwide engineering analysis of compliance cost and emissions reductions. The EPA estimated costs and expected emissions reductions of the final and alternative regulatory options for each II&S facility individually and aggregated them to calculate industry-wide impacts for the rule. We calculate cost and emissions impacts of the final and alternative regulatory requirements over a 10-year analytical timeframe from 2026 to 2035. This timeframe spans the projected first year of full implementation of the final NESHAP amendments for BF/BOPF fugitive emission sources (under the assumption that the final action is final in 2024), 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.

1.2.3 *Summary of Cost and Emissions Impacts*

The final requirements discussed in Section **Error! Reference source not found.** are presented in **Error! Reference source not found.** below. The final amendments to the NESHAP for II&S Manufacturing Facilities (Subpart FFFFF) constitute significant regulatory action under E.O. 12866 Section 3(f)(1), as amended by E.O. 14094. This rulemaking is a significant regulatory action because it is likely to have an annual effect on the economy of $200 million or more in any one year or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or state, local, territorial or tribal governments or communities. Specifically, the final amendments to HAP fugitive standards under Subpart FFFFF are projected to reduce HAP emissions by about 64 short tons per year and $PM_{2.5}$ emissions by about 470 short tons per year. The EPA monetized the projected benefits of reducing $PM_{2.5}$ emissions in terms of the value of avoided premature deaths and illnesses attributable to $PM_{2.5}$. The equivalent annualized value of monetized benefits related to $PM_{2.5}$ emissions reductions is greater than $200 million per year, as seen in Table 1-2.

Table 1-1: Current and Final Standards for II&S Facility Emissions

Emissions Segment	Current Standard	Final Standard
Fenceline Monitoring	No Requirement	Requirement with Work Practice Action Level for Cr
BF Unplanned Bleeder Valve Openings	No Standard	Work Practices
BF Planned Bleeder Valve Openings		8% Opacity Limit
BF/BOPF Slag Processing, Handling, and Storage		10% Opacity Limit
BF Bell Leaks		Work Practices; 10% Opacity Action Level
BF Iron Beaching		MACT Floor and Work Practices
BOPF Shop Fugitives	20% Opacity Limit	20% Opacity Limit and Work Practices
Sinter Plant: D/F and PAH	VOC and Oil Content Surrogate Standard	Limit based on addition of ACI
Sinter Plant: Hg	No Standard	BTF
Sinter Plant: COS, HCl	No Standard	MACT Floor
BOPF: HCl, THC, D/F		
BF/BF stoves: HCl, THC		

Error! Reference source not found. presents projected emissions reductions, health benefits, compliance costs, and net benefits from the final amendments to the NESHAP for II&S facilities. Health benefits, compliance costs and net benefits are presented in terms of present-value (PV) and equivalent annualized value (EAV) over the period 2026–2035, discounted back to 2024. The EAV represents a flow of constant annual values that would yield a sum equivalent to the PV. PM reductions, some fraction of which are expected to be $PM_{2.5}$, are expected to occur as result of implementing the final standards for BF/BOPF fugitive emissions sources. The EPA monetized the projected benefits of reducing $PM_{2.5}$ emissions in terms of the value of avoided premature mortality and morbidity to particulate matter; the estimated PM-attributable benefits are quantified using two alternative estimates of the risk of mortality from long-term exposure to fine particles. Net benefits are calculated as monetized health benefits minus compliance costs. EPA did not monetize benefits of HAP reductions or non-health benefits of $PM/PM_{2.5}$ reductions, both of which are expected to be positive.

Table 1-2: Monetized Benefits, Compliance Costs, Net Benefits, Emissions Reductions, and Non-Monetized Benefits for the Final NESHAP Amendments, 2026–2035, Discounted to 2024 (million 2022$[3])[a]

	3 Percent Discount Rate		7 Percent Discount Rate	
	PV	EAV	PV	EAV
Monetized Health Benefits[b]	$1,800 and $3,700	$200 and $420	$1,300 and $2,600	$170 and $340
Compliance Costs	$45	$5.3	$36	$5.1
Net Benefits	$1,800 and $3,700	$190 and $410	$1,200 and $2,600	$160 and $330
Emissions Reductions	2026–2035			
HAP	640 short tons			
PM	18,000 short tons			
$PM_{2.5}$	4,700 short tons			
D/F	72 grams			
PAH	54 short tons			
Hg	530 pounds			
Non-Monetized Benefits	HAP benefits from reducing 1,100 short tons of HAP from 2026–2035 Benefits from reducing 72g of D/F, 54 tons of PAH, 530lbs of Hg from 2026–2035 Non-health benefits from reducing 18,000 tons of PM, of which 4,700 tons is $PM_{2.5}$, from 2026–2035 Visibility Effects Reduced Ecosystem/Vegetation Effects			

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Monetized benefits include health benefits associated with reducing $PM_{2.5}$ emissions. The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2017) and Turner et al. (2016) studies and presented at real discount rates of 3 and 7 percent. The two benefits estimates are separated by the word “and” to signify that they are two separate estimates. Benefits from HAP reductions remain unmonetized and are thus not reflected in the table.

1.3 Organization of this Report

The remainder of this report details the methodology and the results of the RIA. Chapter 2 presents a profile of the steel manufacturing industry. Chapter 3 describes emissions, emissions control options, and engineering costs. Chapter 4 presents the benefits analysis, including a qualitative discussion of the unmonetized benefits associated with HAP emissions reductions. Chapter 5 presents an analysis and discussion of economic impacts. Chapter 6 presents a comparison of benefits and costs. Chapter 7 contains the references for this RIA.

2 INDUSTRY PROFILE[3]

2.1 Introduction

This industry profile supports the regulatory impact analysis (RIA) of the final amendments to the NESHAP for II&S mills. Iron is produced from iron ore, and steel is produced by progressively removing impurities from iron ore and scrap metal. The North American Industry Classification System code (NAICS) for Iron and Steel Mills and Ferroalloy Manufacturing is 331110, and all integrated iron and steel manufacturing operations fall within this classification.

There are two primary methods for manufacturing steel. The first uses a blast furnace to convert iron ore and other raw materials into molten iron, and then produces steel in a basic oxygen process furnace (BOPF) using primarily molten iron and scrap metal. This is the BF/BOPF process, and is the method used by II&S manufacturing facilities. The other method is the electric arc furnace (EAF), which primarily recycles scrap steel into new steel products. The United States produced 87 million metric tons of raw steel in 2021, about 29 percent of which was produced by the BF/BOPF process in II&S facilities. The remainder was produced at EAF facilities (USGS, 2022a). Steel is a primary input to automobiles, home appliances, and residential construction, so demand for steel is a derived demand that depends on an array of final products.

Figure 2-1 illustrates the four-step production process for manufacturing steel products at II&S facilities. The first step is iron making. Primary inputs to the iron making process are iron ore or other sources of iron, coke or coal, and flux. Pig iron is the primary output of iron making and the primary input to the next step in the process, steel making. Metal scrap and flux are also used in steel making. The steel making process produces molten steel that is shaped into solid forms at forming mills. Finishing mills then shape, harden, and treat the semi-finished steel to yield its final marketable condition.

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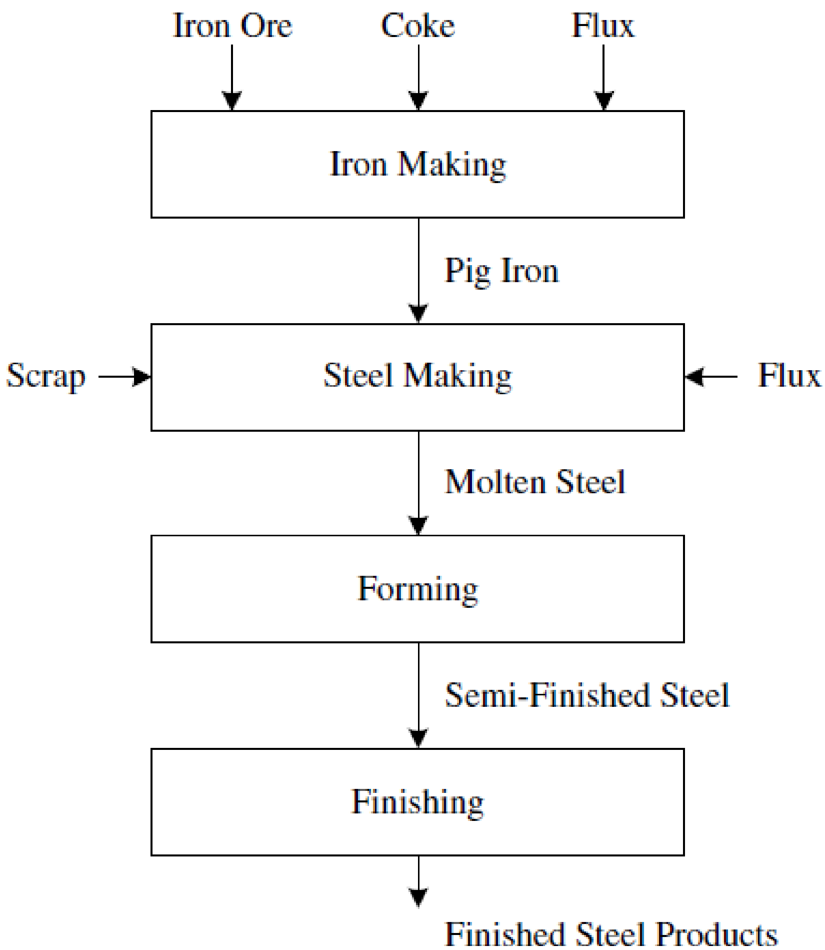
3 This section is derived in part from the *Economic Impact Analysis of Final II&S NESHAP* (U.S. EPA, 2002).

Figure 2-1: The Integrated Steel Making Process



Source: U.S. EPA. 2002. *Economic Impact Analysis of Final II&S NESHAP.* Available here: https://www.epa.gov/sites/default/files/2020-07/documents/iron-steel_eia_neshap_final_09-2002.pdf

2.2 Iron Making

Blast furnaces are the primary site of iron making at integrated facilities where iron ore is converted into more pure and uniform iron. Blast furnaces are tall steel vessels lined with refractory brick. They range in diameter from 20 to 50 feet and in height from 70 to 360 feet.[4] Conveyor systems of carts and ladles carry inputs and outputs to and from the blast furnace.

4 https://www.britannica.com/technology/blast-furnace. Accessed 1/26/2023.

Iron ore, coke, and flux are the primary inputs to the iron making process. Iron ore, which is typically 50 to 70 percent iron, is the primary source of iron for II&S mills. Pellets are the primary source of iron ore used in iron making at integrated steel mills. Iron can also be captured by sintering from fine grains, pollution control dust, and sludge. Sintering ignites these materials and fuses them into cakes that are 52 to 60 percent iron.

Coke is made in ovens that heat metallurgical coal to drive off gases, oil, and tar, which can be collected by a coke by-product plant to use for other purposes or to sell. Coke may be generated by an II&S facility or purchased from a merchant coke producer. Flux is a general name for any material used in the iron or steel making process that is used to collect impurities from molten metal. Limestone is commonly used as flux in blast furnaces, in addition to silica, dolomite, and lime.5

Figure 2-2 shows the iron making process at blast furnaces. Once the blast furnace is fired up, it runs continuously until the lining is worn away. Coke, iron materials, and flux are charged into the top of the furnace. Hot air is forced into the furnace from the bottom . The hot air ignites the coke, which provides the fuel to melt the iron. As the iron ore melts, chemical reactions occur. Coke releases carbon as it burns, which combines with the iron. Carbon bonds with oxygen in the iron ore to reduce the iron oxide to pure iron. The bonded carbon and oxygen leave the molten iron in the form of carbon monoxide, which is the blast furnace gas. Some of the carbon remains in the iron. Carbon is an important component of iron and steel because it allows iron and steel to harden when they are cooled rapidly.

Flux combines with the impurities in molten iron to form slag. Slag separates from the molten iron and rises to the surface. A tap removes the slag from the iron while molten iron, called hot metal, is removed from a different tap at 2,800 to 3,000°F. Producing a metric ton of iron from a blast furnace requires about 1.6 metric tons of iron ore, 450 kg of coke (740 kg of coal), and 120 kg of limestone.6

Hot metal may be transferred directly to steel making furnaces. Hot metal that has cooled and solidified is called pig iron. Pig iron is typically used in steel making furnaces, but it also may be cast for sale as merchant pig iron. Merchant pig iron may be used by foundries or electric

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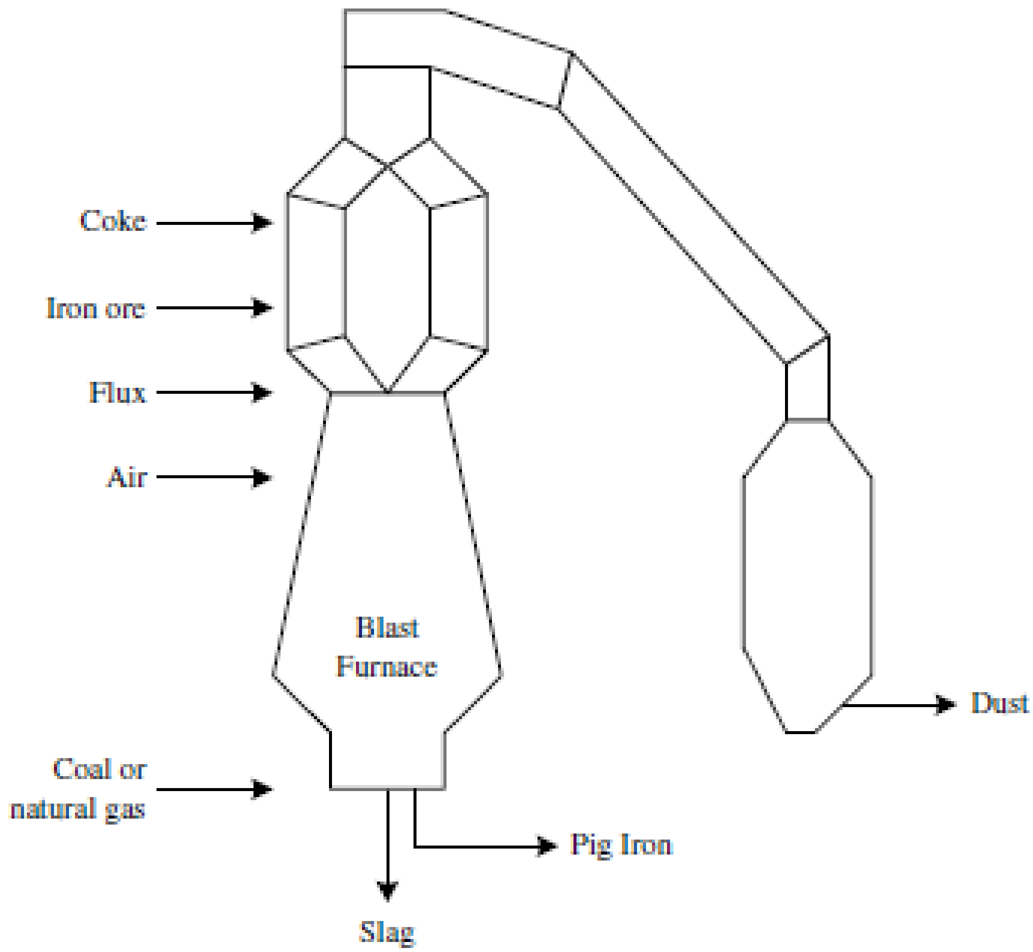
5 https://www.britannica.com/technology/flux-metallurgy. Accessed 1/26/2023.
6 https://worldsteel.org/steel-topics/raw-materials/. Accessed 1/26/2023.

arc furnace (EAF) facilities that do not have iron making capabilities. In 2021, blast furnaces in the United States produced 22 million short tons of pig iron (USGS, 2022a).

Figure 2-2: Iron Making Process: Blast Furnace



Source: U.S. EPA, Office of Compliance. 1995. *EPA Office of Compliance Sector Notebook Project: Profile of the Iron and Steel Industry*. Washington, DC: Environmental Protection Agency.

2.3 Steel Making

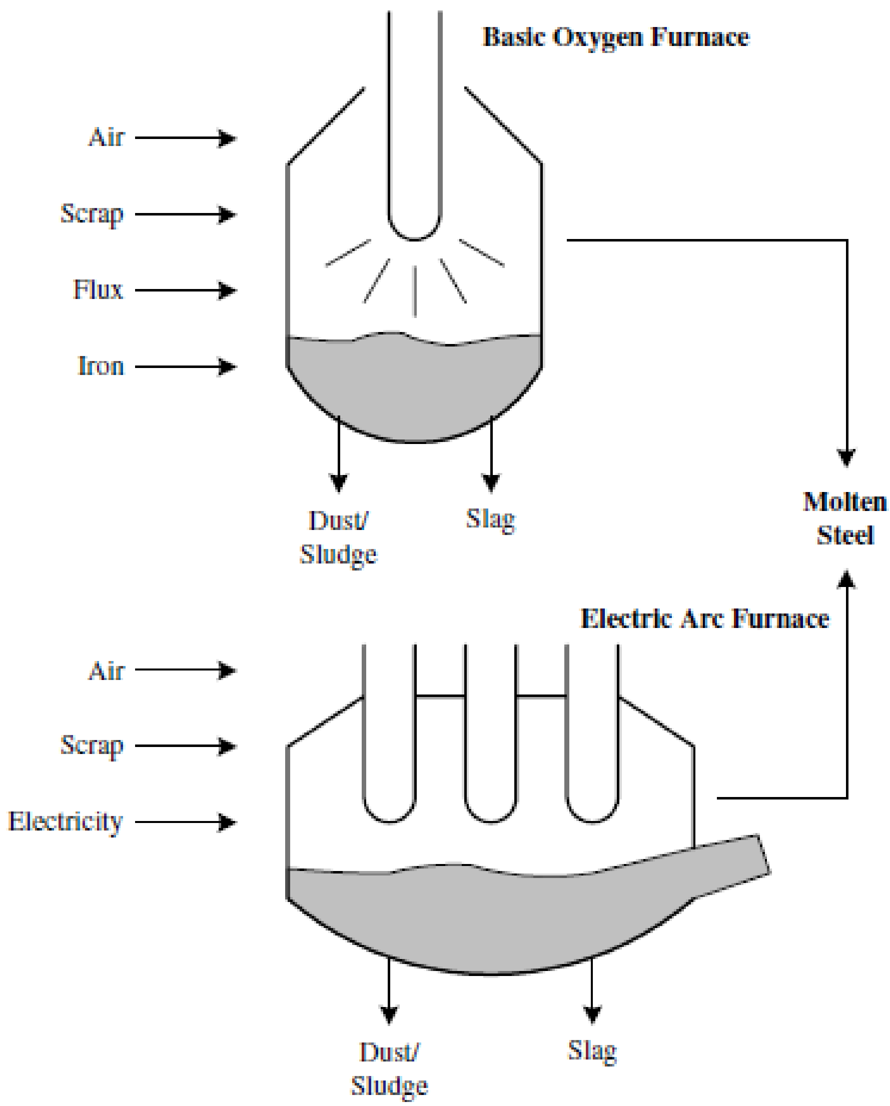
Steel making is carried out in basic oxygen process furnaces or in EAFs, while iron making is only carried out in blast furnaces. Basic oxygen furnaces are the standard steel making furnace used at integrated mills; EAFs are the standard furnace at mini-mills since they use scrap metal efficiently on a small scale. Open hearth furnaces were used to produce steel prior to 1991 but have not been used in the United States since that time.

Hot metal or pig iron is the primary input to the steel making process at integrated mills. Hot metal accounts for up to 70-712 percent of the iron charged into a steel making furnace.[7] Scrap metal is also used, which either comes as waste from other mill activities or is purchased on the scrap metal market. Scrap metal must be carefully sorted to control the alloy content of the steel. Direct-reduced iron (DRI) may also be used to increase iron content, particularly in EAFs that use mainly scrap metal for the iron source. DRI is iron that has been formed from iron ore by a chemical process, directly removing oxygen atoms from the iron oxide molecules.

Figure 2-3 shows the steel making process at basic oxygen furnaces and EAFs. At basic oxygen furnaces, hot metal and other iron sources are charged into the furnace. An oxygen lance is lowered into the furnace to inject high purity oxygen—99.5 to 99.8 percent pure—to minimize the introduction of contaminants. Some basic oxygen furnaces insert the oxygen from below. Energy for the melting of scrap and cooled pig iron comes from the oxidation of silicon, carbon, manganese, and phosphorous. Flux is added to collect the oxides produced in the form of slag and to reduce the levels of sulfur and phosphorous in the metal. Approximately 30-50 kilograms of lime are needed to produce a metric ton of steel.[8] The basic oxygen process can produce approximately 220 tons in 45 minutes.[9] When the process is complete, the furnace is tipped and the molten steel flows out of a tap into a ladle.

7 https://www.wermac.org/steel/steelmaking.html. Accessed 3/15/2023.
8 https://britishlime.org/technical/iron_and_steel.php. Accessed 1/26/2023.
9 https://www.wermac.org/steel/steelmaking.html. Accessed 1/26/2023.

Figure 2-3: Steel Making Process: Basic Oxygen Process Furnace and Electric Arc Furnace

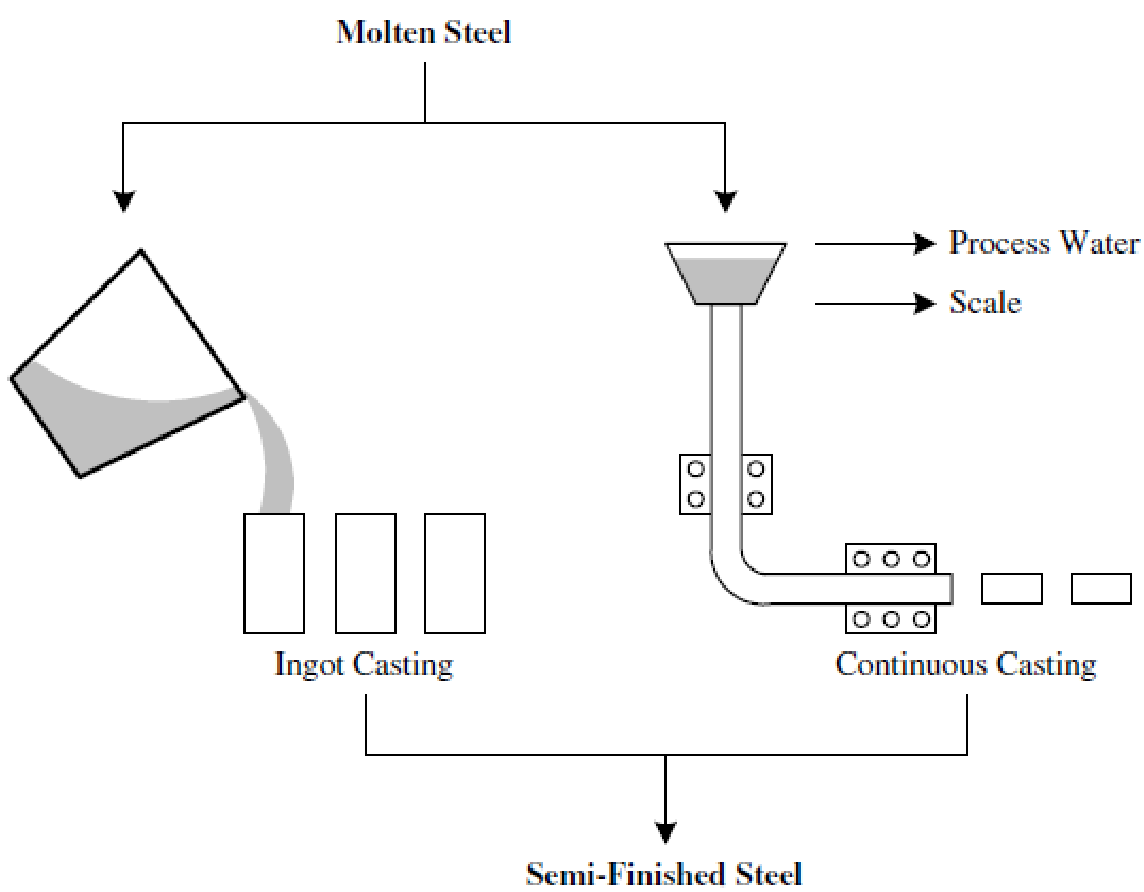


Source: U.S. EPA, Office of Compliance. 1995. *EPA Office of Compliance Sector Notebook Project: Profile of the Iron and Steel Industry*. Washington, DC: Environmental Protection Agency.

Steel often undergoes additional, referred to as secondary, metallurgical processes after it is removed from the steel making furnace. Secondary steel making takes place in vessels, smaller furnaces, or the ladle. These sites do not have to be as strong as the primary refining furnaces because they are not required to contain the powerful primary processes. Secondary steel making can have many purposes, such as removal of oxygen, sulfur, hydrogen, and other gases by exposing the steel to a low-pressure environment; removal of carbon monoxide through the use of deoxidizers such as aluminum, titanium, and silicon; and changing of the composition of unremovable substances such as oxides to further improve mechanical properties.

Molten steel transferred directly from the steel making furnace is the primary input to the forming process. Forming must be done quickly before the molten steel begins to cool and solidify. Two generalized methods are used to shape the molten steel into a solid form for use at finishing mills: ingot casting and continuous casting machines (see Figure 2-4). Ingot casting is the traditional method of forming molten steel in which the metal is poured into ingot molds and allowed to cool and solidify. However, continuous casting currently accounts for greater than 99 percent of steel production (USGS, 2022a). Continuous casting, in which the steel is cast directly into a moving mold on a machine, reduces loss of steel in processing.

Figure 2-4: Ingot Casting and Continuous Casting



Source: U.S. EPA, Office of Compliance. 1995. *EPA Office of Compliance Sector Notebook Project: Profile of the Iron and Steel Industry*. Washington, DC: Environmental Protection Agency.

2.4 Steel Mill Products

Carbon steel is the most common type of steel by metallurgical content (see Table 2-1). By definition, for a metal to be steel it must contain carbon in addition to iron. Increases in carbon content increase the hardness, tensile strength, and yield strength of steel but can also make steel susceptible to cracking. Alloy steel is the general name for the wide variety of steels that manipulate alloy content for a specific group of attributes. Alloy steel does not have strict alloy limits but does have desirable ranges. Some of the common alloy materials are manganese, phosphorous, and copper. Stainless steel must have a specific mix of at least 10.12 percent chromium, less than 1.2 percent carbon and other alloying elements, and at least 50 percent iron.10

Table 2-1: Steel Type by Metallurgical Content, 2021

	Thousand Metric Tons	Percent
Carbon Steel	81,700	95%
Stainless Steel	2,250	3%
All Other Alloy Steel	1,970	2%
Total	85,900	100%

Source: United States Geological Survey (USGS). 2021. *Iron and Steel* [table-only release]. Metals and Minerals: USGS Minerals Yearbook 2021, volume 1. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

Semi-finished steel formed from the casting process are passed through processing lines at finishing mills to give the steel its final shape. At rolling mills, steel slabs are flattened or rolled into pipes. At hot strip mills, slabs pass between rollers until they have reached the desired thickness. The slabs may then be cold rolled in cold reduction mills. Cold reduction, which applies greater pressure than the hot rolling process, improves mechanical properties, machinability, and size accuracy, and produces thinner gauges than possible with hot rolling alone. Cold reduction is often used to produce wires, tubes, sheet and strip steel products.

After the shape and surface quality of steel have been refined at finishing mills, the metal often undergoes further processes for cleansing. Pressurized air or water and cleaning agents are the first step in cleansing. Acid baths during the pickling process remove rust, scales from processing, and other materials. The cleaning and pickling processes help coatings to adhere to

10 https://www.aperam.com/stainless/what-is-stainless-steel/. Accessed 1/16/2023.

the steel. Metallic coatings are frequently applied to sheet and strip to inhibit corrosion and oxidation, and to improve visual appearance. The most common coating is galvanizing, which is a zinc coating. Other coatings include aluminum, tin, chromium, and lead. Semi-finished products are also finished into pipes and tubes. Pipes are produced by piercing a rod of steel to create a pipe with no seam or by rolling and welding sheet metal.

Slag is generated by iron and steel making. Slag contains the impurities of the molten metal, but it can be sintered to capture the iron content. Slag can also be sold for use by the cement industry, for railroad ballast, and by the construction industry.

2.5 Uses and Consumers of Steel Mill Products

Table 2-2 shows world steel consumption over a variety of categories. Building and infrastructure construction accounts for more than half of global steel consumption. U.S. Securities and Exchange Commission filings provide insight into the end-users of steel produced by the two firms that own all II&S facilities in the U.S., U.S. Steel and Cleveland-Cliffs Inc. The automotive industry is the largest end-user of domestic steel produced by II&S facilities, accounting for about 43 percent of U.S. Steel steel shipments and 40 percent of Cleveland-Cliffs Inc.'s total revenue .11 Since steel demand is derivative of demand for automobiles and construction, sales of U.S. steel manufactures sales are particularly responsive to underlying changes in underlying macroeconomic conditions that affect demand for those end products (e.g., changes in interest rates).

Table 2-2: Global Steel Consumption by Category, 2019

Category	Share
Buildings and Infrastructure	52%
Automotive	12%
Metal Products	10%
Mechanical Equipment	16%
Other Transport	5%
Domestic Appliances	2%
Electrical Equipment	3%

Source: https://worldsteel.org/about-steel/steel-facts/. Accessed 1/26/2024.

2.6 Industry Organization

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

There are currently eight II&S manufacturing facilities in the United States; Table 2-3 lists these facilities. These facilities are all in the midwestern United States, across five states: three in Indiana, two in Ohio, and one each in Illinois, Michigan, and Pennsylvania. A ninth facility, the Great Lakes Works in Ecorse, Michigan (owned by U.S. Steel) closed in 2019. The facilities range in steel capacity from 2.5 to 7.5 million metric tons per year. Three II&S facilities use on-site sinter plants: Burns Harbor Works, Indiana Harbor Works, and Gary Works. The Dearborn Works permanently idled their hot strip mill, anneal, and temper operations in 2020.12 The number of II&S has decreased from 20 (owned by 14 firms) in 2001 to 8 (owned by two firms). As previously mentioned, two parent companies account for all the raw steel from the BF/BOPF process. Cleveland-Cliffs Inc. facilities account for 59 percent of II&S capacity and U.S. Steel facilities account for the remaining 41 percent. There are also 88 EAF facilities owned by 36 firms. Since Cleveland-Cliffs Inc. and U.S. Steel own both II&S facilities and EAF facilities, there are 96 steel manufacturing facilities owned by 36 firms.

Table 2-3: II&S Facilities

Ultimate Parent Company	Facility	Location	Steel Capacity (million metric tons/year)	Sinter Plant
Cleveland-Cliffs Inc.	Burns Harbor Works	Burns Harbor, IN	5	Yes
	Cleveland Works	Cleveland, OH	3	No
	Dearborn Works	Dearborn, MI	2.5	No
	Indiana Harbor Works	East Chicago, IN	5.5	Yes
	Middletown Works	Middletown, OH	3	No
U.S. Steel	Gary Works	Gary, IN	7.5	Yes
	Granite City Works	Granite City, IL	2.8	No
	Mon Valley Works	Braddock, PA	2.9	No

Sources: US Steel and Cleveland-Cliffs websites https://www.clevelandcliffs.com/operations/steelmaking https://www.ussteel.com/about-us/locations.

12 https://www.clevelandcliffs.com/operations/steelmaking/dearborn-works#:~:text=During%202020%2C%20the%20Dearborn%20Works,temper%20operations%20were%20permanently%20idled. Accessed 1/23/2023.

Table 2-4: EAF Facilities

Firm Name	Firm-Owned EAFs
Acciaierie Valbruna S.p.a.	1
Acerinox S.A.	1
Allegheny Technologies Inc.	1
Berkshire Hathaway Inc.	1
Bluescope Steel Limited	1
Carpenter Technology Corp.	2
Charter Manufacturing Company, Inc.	2
Cleveland-Cliffs Inc.	4
Commercial Metals Company	9
Ellwood Group, Inc.	2
Evraz PLC	1
G. O. Carlson, Inc.	1
Gerdau S.A.	10
Grupo Simec, S.A.B. De C.V.	2
Haynes International, Inc.	1
Höganäs Holding AB	1
JSW Steel Limited	1
KCI Holdings, Inc.	1
Kyoei Steel Ltd.	1
Leggett & Platt, Inc.	1
Melrose Industries PLC	1
Nippon Steel Corporation	1
NLMK, PAO	1
Nucor Corporation	21
Outokumpu	1
Schnitzer Steel Industries, Inc.	1
SSAB U.S. Holding, Inc.	2
Steel Dynamics, Inc.	6
Sumitomo Corporation	1
Swiss Steel Holding AG	1
Tenaris Global Services (USA) Corporation	1
Timkensteel Corporation	2
U.S. Steel	2
Universal Stainless & Alloy Products, Inc.	1
Vallourec Deutschland Gmbh	1
Whemco Inc.	1
Grand Total	**88**

Source: Information on existing EAFs from AIST publication "2021 AIST Electric Arc Furnace Roundup"

Estimated employment in iron and steel mills is 86,000 (USGS, 2022a), down from about 160,000 in 2000 and 110,000 in 2010.13 As detailed in Section 2.7.4, United States steel production has been trending strongly towards EAF and will likely continue to do so for the foreseeable future. The fall in employment is closely related to the shift in production to EAF, as EAF steel requires fewer labor-hours to produce.14

2.6.1 *Horizontal and Vertical Integration*

Whether a firm is vertically or horizontally integrated depends on the business activity that the parent company does 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 steel industry, a company that operates an II&S facility might also own the taconite iron ore mining and processing facilities, coal mines, and coking facilities, all of which contribute primary inputs to II&S facilities. 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. Cleveland-Cliffs Inc. and U.S. Steel own all taconite iron ore mining and processing facilities in the United States (see Table 2-5). 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 2-6). Finally, Cleveland-Cliffs Inc. owns a facility that produces hot-briquetted iron, a lower-carbon iron feedstock used primarily as a substitute for scrap metal in EAFs.15 U.S. Steel and Cleveland-Cliffs Inc. could also be considered horizontally integrated at the steel manufacturing stage of production because they represent large portions of the industry (and the entirety of the II&S portion of the industry).

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13 USGS Mineral Commodity Summaries, available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information. Accessed 1/27/2023.

14 https://www.aei.org/carpe-diem/the-main-reason-for-the-loss-of-us-steel-jobs-is-productivity-and-technology-not-imports-and-theyre-not-coming-back/. Accessed 1/27/2023.

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

Table 2-5: U.S. Taconite Iron Ore Facility Ownership, Production, and Capacity

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

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. (2022b). *Iron Ore* [tables only release]. U.S. Geological Survey Minerals Yearbook – 2020. Available at https://www.usgs.gov/centers/national-minerals-information-center/iron-ore-statistics-and-information.

Table 2-6: 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: Firms owning II&S facilities displayed in bold.

2.6.2 *Firm Characteristics*

Table 2-7 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. Both companies reported similar sales revenue in 2021 (just over $20 billion) and employed approximately 25,000 workers worldwide.

Table 2-7: 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

2.7 Market Conditions

2.7.1 *Domestic Production and Consumption*

Table 2-8 shows steel production, consumption, and prices in the United States from 2010 to 2021. Steel production, shipments, and consumption were broadly stable over the period. Steel production and consumption dipped sharply due to the economic slowdown caused by the COVID-19 pandemic, but rebounded in 2021. Table 2-9 shows steel mill product shipments by product type. Hot-rolled coil sheets are the most produced steel mill product, accounting for about 228 percent of all shipments in 2019, and therefore are a useful surrogate for all product prices.

Table 2-8: U.S. Steel Production, Consumption, and Prices, 2010-2021 (volumes in thousand metric tons)

Year	Raw Steel Production	Shipments	Consumption	Hot Rolled Coil Steel ($/metric ton)[a]	HRC Price Adjusted to 2021 USD	All Steel Mill Products PPI
2010	80,500	75,700	82	620	1,182	191.7
2011	86,400	83,300	90	735	1,307	216.2
2012	88,700	87,000	98	652	1,249	208
2013	86,900	86,600	100	634	1,338	195
2014	88,200	89,100	107	647	1,326	200.2
2015	78,800	78,500	99	454	1,124	177.1
2016	78,500	78,500	93	533	1,430	167.8
2017	81,600	82,500	99.4	621	1,407	187.4
2018	86,600	86,400	101	835	1,604	211.1
2019	87,800	87,300	99.6	600	1,269	204
2020	72,700	73,500	82.9	607	1,533	184.4
2021	87,000	88,000	98	1,610	1,610	348.5

[a] Steel prices reflect HRC steel USD/metric ton average monthly prices. Hot rolled sheets are the most produced steel in the United States; see Table 15. HRC prices were adjusted to 2021 values using the PPI for hot rolled sheet steel. The PPI for steel mill products index year: 1982 = 100.

Sources:

USGS. *Iron and steel.* Mineral Commodity Summaries 2011-2022. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

U.S. Bureau of Labor Statistics. (2022). *Producer Price Index by commodity: metals and metal products: Hot rolled steel sheet and strip, including tin mill products* [WPU101703].

U.S. Bureau of Labor Statistics. (2022). *Producer Price Index by commodity: metals and metal products: Steel mill products.* [WPU1017].

Investing.com (2024) *US Midwest Domestic Hot-Rolled Coil Steel Futures Historical Data. https://www.investing.com/commodities/us-steel-coil-futures-historical-data.*

Table 2-9: Shipments of Steel Mill Products by Type, 2019 and 2020

	Quantity (thousand metric tons)		Percent	
Steel mill products:	2019	2020	2019	2020
Ingots, blooms, billets, and slabs	525	424	0.6	0.58
Wire rods	2,860	1,940	3.28	2.65
Structural shapes, heavy	6,240	5,310	7.15	7.22
Plates, cut lengths	5,840	5,120	6.7	6.96
Plates, in coils	2,280	1,680	2.62	2.28
Rails	814	721	0.93	0.98
Railroad accessories	359	295	0.41	0.4
Bars, hot-rolled	4,560	3,210	5.23	4.37
Bars, light-shaped	2,060	1,410	2.36	1.92
Bars, reinforcing	7,740	6,330	8.87	8.61
Bars, cold finished	1,070	721	1.22	0.98
Pipe and tubing, standard pipe	843	532	0.97	0.72
Pipe and tubing, oil country goods	1,700	868	1.95	1.18
Pipe and tubing, line pipe	589	292	0.68	0.4
Pipe and tubing, mechanical tubing	510	376	0.58	0.51
Pipe and tubing, pipe piling	210	151	0.24	0.21
Pipe and tubing, pressure tubing	16	16	0.02	0.02
Pipe and tubing, structural	425	383	0.49	0.52
Wire	445	366	0.51	0.5
Tin mill products, blackplate	43	9	0.05	0.01
Tin mill products, tinplate	875	1,130	1	1.54
Tin mill products, tin free steel	190	36	0.22	0.05
Tin mill products, tin coated sheets	69	58	0.08	0.08
Sheets, hot-rolled	19,900	17,800	22.82	24.27
Sheets, cold-rolled	9,700	8,490	11.11	11.56
Sheets and strip, hot dip galvanized	14,100	12,600	16.11	17.09
Sheets and strip, electrogalvanized	570	415	0.65	0.56
Sheets and strip, other metallic coated	2,100	2,240	2.4	3.04
Strip, hot-rolled	82	83	0.09	0.11
Strip, cold-rolled	582	493	0.67	0.67
Total	87,300	73,500	100	100

Source: USGS. (2020). *Iron and steel* [tables only release]. U.S. Geological Survey Minerals Yearbook – 2020. https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information

2.7.2 *Prices*

Table 2-8 shows the price of hot-rolled coil steel in both nominal and 2021 dollars. Steel prices spiked in 2021, doubling year-over-year from 2020 to 2021. This was a temporary spike, as steel production struggled to keep with demand from the construction, automotive, and home appliance sectors and higher energy and raw material costs.16 Prices have since returned to historical norms, with hot-rolled coil steel futures trading at 775 $/metric ton in January 2024.17

2.7.3 *Foreign Trade*

Table 2-10 shows steel mill product imports and exports from 2010-2021. The United States was a net importer over the time period, with the volume of the trade deficit peaking in 2014. Mexico and Canada account for the vast majority of steel mill product exports, while the U.S. imports significant quantities from Canada, Mexico, Brazil, South Korea, and Japan. Table 2-11 shows the breakdown of imports and exports by country.

Table 2-10: U.S. Steel Mill Products Imports and Exports, 2010-2021 (thousand metric tons)

Year	Imports	*Finished*	*Semi-finished*[a]	Exports	*Finished*	*Semi-finished*
2010	21,700	17,100	4,600	11,000	10,400	609
2011	25,900	19,800	6,000	12,200	11,300	904
2012	30,400	23,500	6,900	12,500	11,700	817
2013	29,200	22,600	6,600	11,500	11,100	443
2014	40,200	30,600	9,600	10,900	10,600	289
2015	35,200	28,600	6,600	9,050	8,900	138
2016	30,000	23,900	6,000	8,450	8,400	111
2017	34,600	26,800	7,800	9,550	9,400	143
2018	30,600	23,300	7,300	7,980	7,900	94
2019	25,300	19,100	6,200	6,700	6,600	72
2020	20,000	14,600	5,300	6,810	6,700	110
2021	25,000	18,000	6,700	8,300	8,100	100

[a] Exports and imports rounded to 100,000 metric tons, besides semi-finished exports due to small values.
Source: USGS. (2022). *Iron and steel* [tables only release]. U.S. Geological Survey Minerals Yearbook – 2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

16 https://www.yahoo.com/video/steel-prices-set-upturn-war-131101512.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAG6jjiF8suwUlzCn-zK8PA5PVGx2b0VE2O-Md5LDPv7k8NcrOBoT2T6KN2RQOcXjhZdbOJvjE5Mh8L1vPnxMWxI_BxAPrjlISS1yDyXJ4onKuQhEj-PW_0x3ykCsISBugeXHC0ApgncxsJU2Z8win1H_P9SXnFyOnwtmD72vLZbD. Accessed 1/27/2023.

17 https://www.investing.com/commodities/us-steel-coil-futures-historical-data. Accessed 1/27/2023.

Table 2-11: U.S. Steel Mill Product Imports and Exports by Country, 2019 and 2020 (thousand metric tons)

Country	2019		2020	
	Imports	Exports	Imports	Exports
Argentina	178	8	27	6
Belgium	114	28	54	14
Brazil	3,830	38	3,670	24
Canada	5,030	2,940	4,730	2,850
China	498	55	342	65
France	168	8	90	5
Germany	966	21	809	14
Italy	535	18	167	15
Japan	1,140	15	732	14
Republic of Korea	2,340	34	1,830	25
Mexico	3,370	3,050	3,010	2,630
Netherlands	499	6	420	3
Russia	977	--	390	--
Spain	404	24	262	12
Sweden	203	9	138	10
Taiwan	753	13	520	8
Turkey	297	--	510	--
United Kingdom	231	27	190	16
Vietnam	602	--	285	--
Other	3,220	404	1,810	1,090
Total	25,300	6,700	20,000	6,810

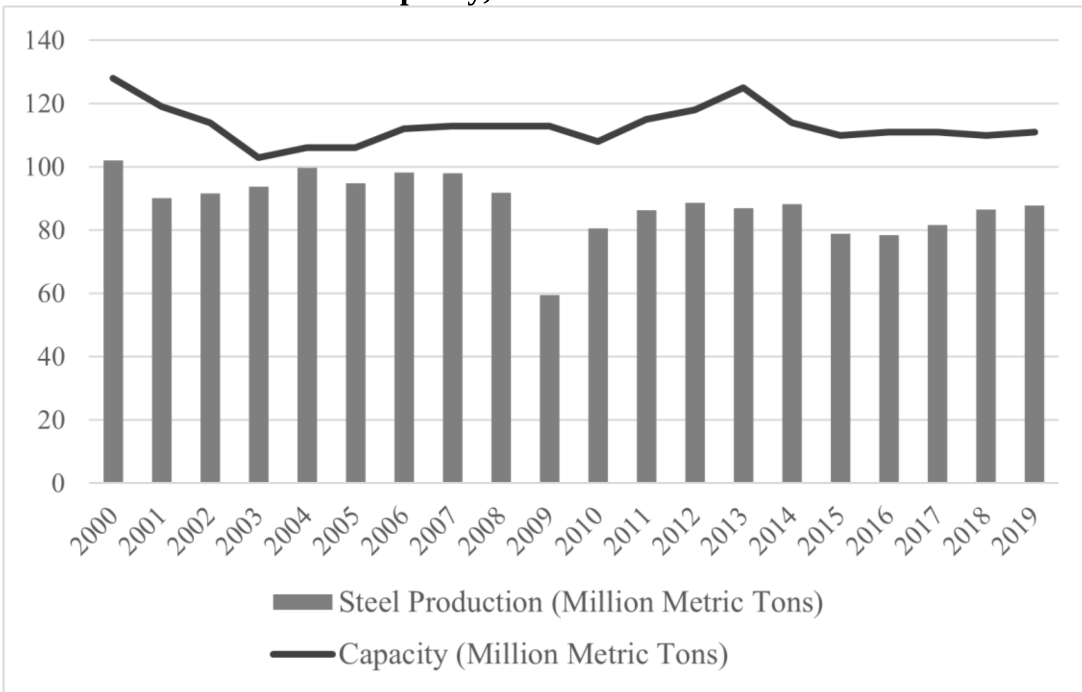
Source: USGS. (2022). *Iron and steel* [tables only release]. U.S. Geological Survey Minerals Yearbook – 2020. Available at: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

2.7.4 *Trends and Projections*

Figure 2-5 shows U.S. steel production and capacity from 2000 to 2019. Total steel production dropped markedly from 2008 to 2009, but has been around 80-90 million metric tons per year since 2011. Total capacity has been steady since 2015. Figure 2-6 shows the evolution of the U.S. steel industry from BF/BOPF to EAF production from 2001 to 2021. The share of steel produced by II&S facilities has dropped from 53 percent in 2001 to 29 percent in 2021. The U.S. is a global outlier in this regard: in 2020, only 28 percent of all global steel was produced from EAFs.18

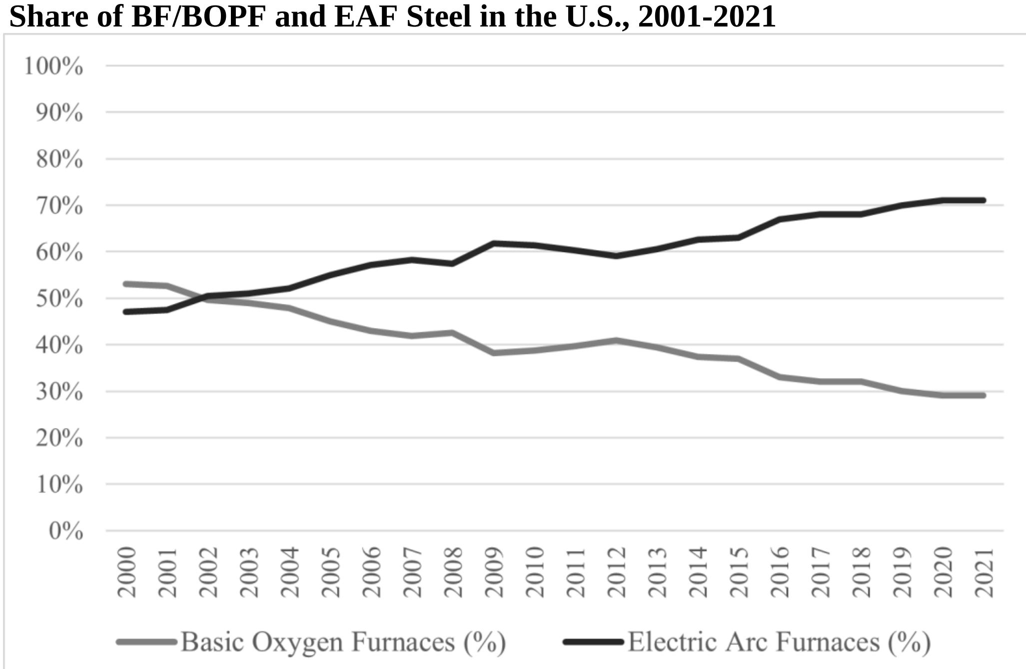
18 https://www.globalefficiencyintel.com/new-blog/2020/9/2/part-2-cleanest-and-dirtiest-countries-for-secondary-eaf-steel-production. Accessed 1/26/2023.

Figure 2-5: Steel Production and Capacity, 2000-2019



Source: USGS Mineral Yearbooks, 2000-2020. Available here: https://www.usgs.gov/centers/national-minerals-information-center/iron-and-steel-statistics-and-information.

Figure 2-6: 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.

The EAF process has been gaining prevalence, especially domestically. 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, 2020). 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 CO2/t of steel produced, while integrated operations emit 2.2 t CO2/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 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 tend to have newer infrastructure and less steel recycling, often along with a greater supply of iron ore or cheap coal (China and India, for instance), 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.

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/BOPF 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 2-3, two II&S 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 claims that, by 2050, EAFs in the United States will make up about 90 percent 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 final NESHAP amendments for the 2026 to 2035 period. The projected costs and emissions impacts are based on facility-level estimates of the costs of meeting the final emission limits and the expected emissions reduction of installing the necessary controls and performing the required work practices. The baseline emissions and emission reduction estimates are based on the number of blast furnaces, basic oxygen furnaces, and sinter plants each facility, iron and steel production capacity at each facility, stack testing data, information and assumptions about current installed controls, and the best available information about emissions factors and activities for each source of fugitive emissions.

3.2 Facilities and Emissions Points

3.2.1 *II&S Manufacturing Facilities*

The NESHAP for II&S facilities covers eight facilities owned by two ultimate parent companies: Cleveland-Cliffs Inc. (five facilities) and U.S. Steel (three facilities). These facilities are all in the midwestern United States, across five states: three in Indiana, two in Ohio, and one each in Illinois, Michigan, and Pennsylvania. A ninth facility, the Great Lakes Works in Ecorse, Michigan (owned by U.S. Steel) closed in 2019. The three sinter plants in the source category are located at Burns Harbor Works, Indiana Harbor Works, and Gary Works. Table 3-1 lists these facilities.

Table 3-1: II&S Facilities

Ultimate Parent Company	Facility	Sinter Plant
Cleveland-Cliffs Inc.	Burns Harbor Works	Yes
	Cleveland Works	No
	Dearborn Works	No
	Indiana Harbor Works	Yes
	Middletown Works	No
U.S. Steel	Gary Works	Yes
	Granite City Works	No
	Mon Valley Works	No

Sources: US Steel and Cleveland-Cliffs Inc. websites: https://www.clevelandcliffs.com/operations/steelmaking https://www.ussteel.com/about-us/locations

II&S facilities manufacture steel by reducing iron ore to iron in a blast furnace and then feeding the molten iron and scrap steel (along with other additives) to a basic oxygen furnace to produce steel. Three facilities include sinter plants. Blast furnaces, basic oxygen furnaces, and sinter plants are the primary sources of HAP and PM emissions from the source category. These three emissions points are discussed in detail in the next section.

3.2.2 *Emission Points at Regulated Facilities*[19]

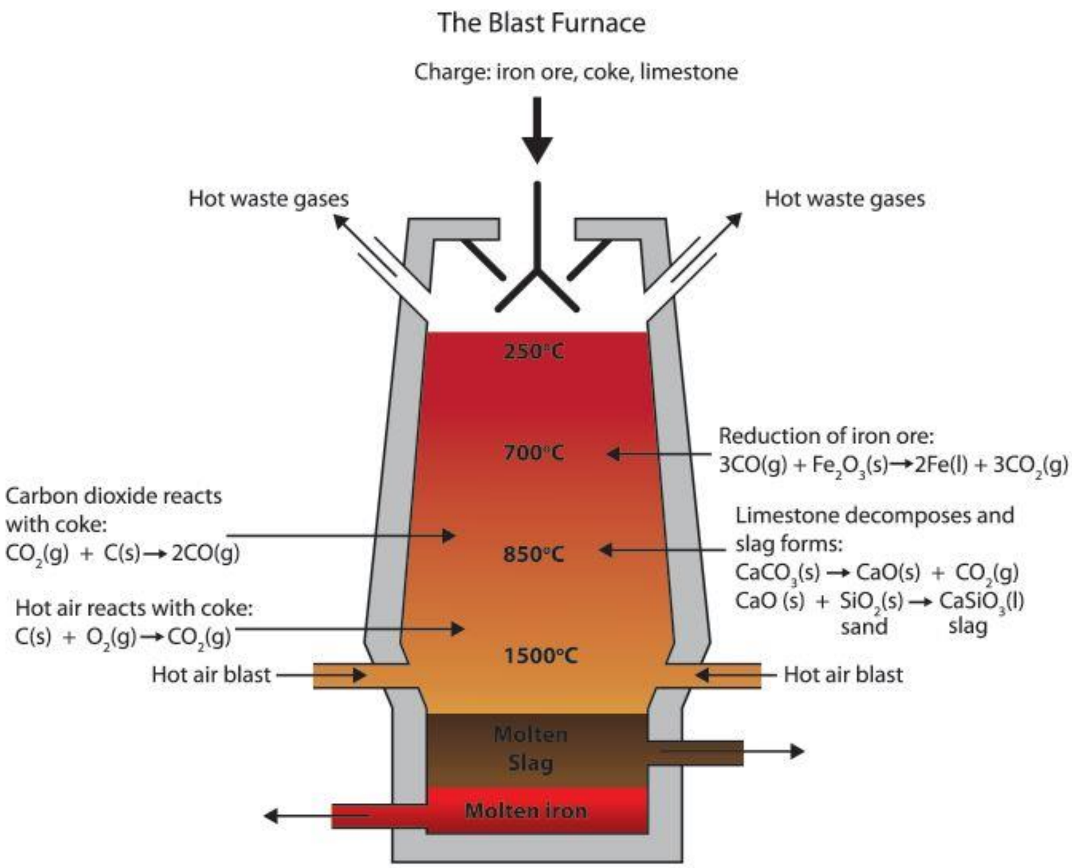
3.2.2.1 Blast Furnaces

The blast furnace converts feedstock (mainly iron ore and taconite iron ore pellets, coke, limestone, and sinter) into molten iron. The feedstock enters at the top of the furnace and descends through the furnace. Coke provides heat and fuel for the chemical reaction in the furnace and provides carbon to reduce the iron oxide by removing oxygen in the form of carbon monoxide (CO). As the feedstock burden descends, it is heated by a countercurrent flow of gas. Hot air is blasted into the bottom of the furnace above the hearth. As the hot air and gas flows upward counter to the feedstock burden, it consumes the coke, reducing the oxygen content of the iron and producing CO. The limestone decomposes into slag, which sits on the top of the molten iron. The iron and slag exit through separate tapholes at the bottom of the furnace, and

19 This section draws heavily from the *National Emissions Standards for Hazardous Air Pollutants (NESHAP) for II&S Plants – Background Information for Proposed Standards* (U.S. EPA, 2001) (EPA 453/R-01-005) and the *Development of Emissions Estimates for Fugitive or Intermittent HAP Emissions Sources for an Example II&S Facility for input to the RTR Risk Assessment* (U.S. EPA, 2019c) (Available at: https://www.regulations.gov/document/EPA-HQ-OAR-2002-0083-0956)

are directed to ladles in the casthouse before transportation to the basic oxygen furnace. Figure 3-1 provides a diagram of the blast furnace and the chemical reactions produced. For more detailed information on iron production, see Section 2.2.

Figure 3-1: Diagram of a Blast Furnace



Source: https://www.metallics.org/pig-iron-bf.html.

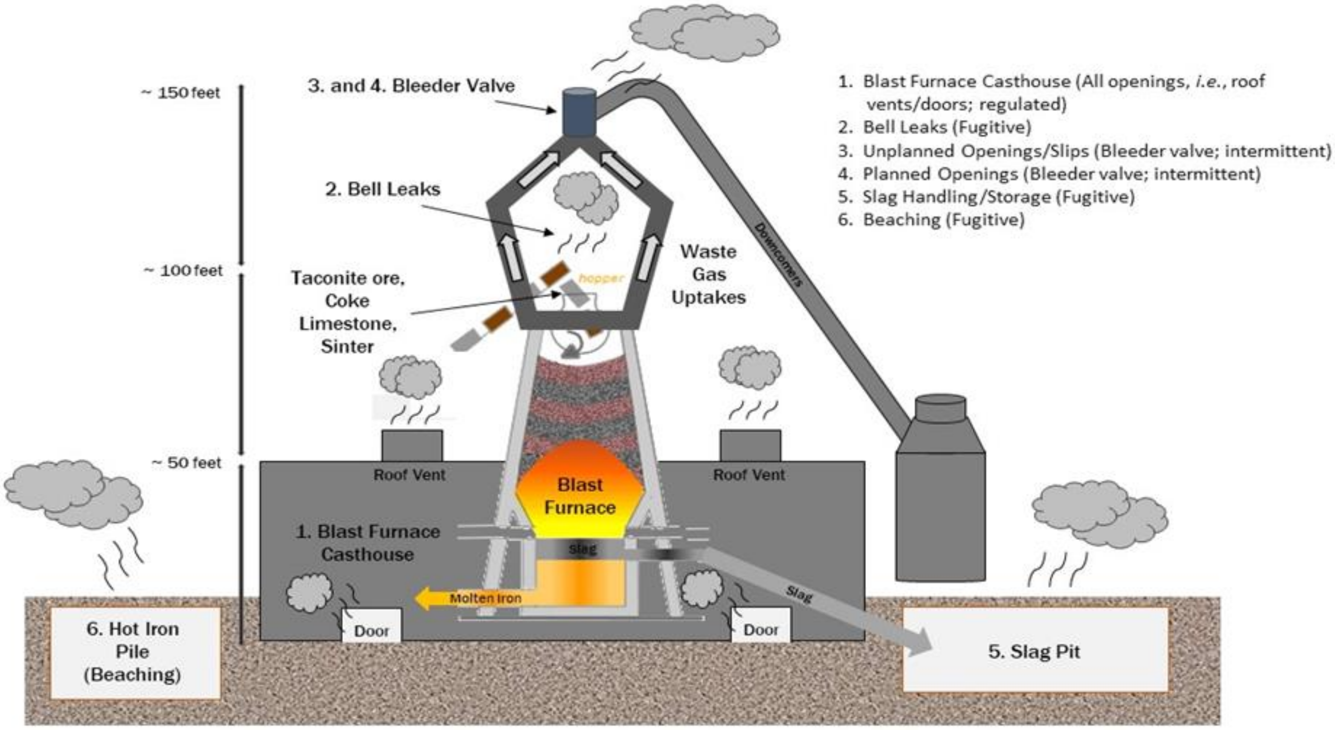
There are several fugitive emissions points in the blast furnace. Figure 3-2 below contains a diagram. Hood systems in the blast furnace casthouse capture emissions and use a scrubber or baghouse to remove PM. Fugitive emissions in the casthouse result from incomplete capture by the emissions systems in place. Fugitive emissions leave the casthouse though roof vents, open doors, and other building openings. Fugitive emissions also occur through bleeder valve openings (both planned and unplanned), bell leaks, slag processing, and iron beaching. The gas leaving the blast furnace is primarily CO and nitrogen and is laden with PM.

There is a pressure/bleeder valve 100-150 feet above the casthouse. Raw material build-up can occasionally create a pressure surge referred to as a "slip" that leads to an unexpected releases of the bleeder valve, lasting from seconds up to about ten minutes. These unexpected bleeder valve openings are referred to as “slips” and occur up to about seven times per month. Bleeder valves are also opened periodically for repair about twice per week. The blast furnace is idled prior to planned bleeder valve openings, leading to lower emissions than during unplanned bleeder valve openings.

Blast furnace bells are part of the hopper system on the blast furnace that allow raw materials to be charged into the furnace without allowing solids or gases to escape into the atmosphere. The typical bell system consists of a large and small bell arranged in a lock system, with the small bell on top of the large bell. Feedstock is placed into the small bell with the large bell closed. Once full, the small bell closes to the atmosphere and its bottom opens into the top of the large bell, which directs the raw materials into the blast furnace. Exhaust air exits the bell through uptakes ducts which directs it to a scrubber or baghouse for PM removal. However, there is a narrow gap in the seal between the bell system and the furnace which allows fugitive emissions to escape. The gap becomes wider over time as the seal wears down, and typically needs to be replaced every five years.

The last two sources of fugitives in the blast furnace are slag handling and iron beaching. Slag is skimmed off the molten iron and exits the casthouse through a system of troughs to large open pits where the slag cools. The slag emissions occur when the slag is dumped into the open pits, stored in the open pits, and removed from the pits. Iron beach occurs when the basic oxygen furnace stops suddenly and cannot receive the molten iron produced by the blast furnace. When this occurs, molten iron from the blast furnace is dumped onto the ground where it emits fumes.

Figure 3-2: Diagram of Blast Furnace Fugitive Emissions



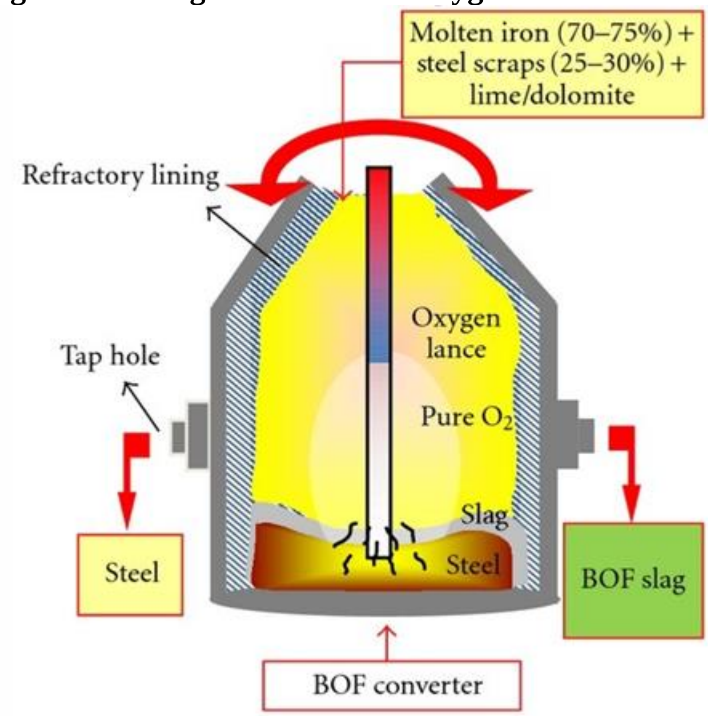
3.2.2.2 Basic Oxygen Process Furnace Shops

The basic oxygen process furnace shop (BOPF shop) receives a charge of molten iron and scrap steel and converts it into molten steel. Molten iron produced by the blast furnace is transported from the BF casthouse by a system of torpedo cars and transferred to a ladle. Each BOPF shop contains at least two vessels that may be operated alternately or used at different stages of the process. The BOPF process consists of the following distinct steps:

1. Charging: the addition of molten iron and metal scrap to the furnace
2. Oxygen blow: introducing oxygen into the furnace to refine the iron
3. Turndown: tilting the vessel to obtain a sample and check temperature
4. Reblow: introducing additional oxygen, if needed
5. Tapping: pouring the molten steel into a ladle
6. Deslagging: pouring residual slag into a slag pot

The furnace is a large, open-mouthed, basic refractory-lined vessel. High-purity oxygen is blown into the vessel to oxidize the carbon and silicon in the molten iron to remove them and to provide heat to melt the scrap. After the oxygen jet starts, lime is added to the furnace to provide a slag of the basicity, and fluorspar and mill scale are added to manipulate slag fluidity. Computations are made to determine the necessary percentage of molten iron, scrap, flux materials, and alloy additions to create steel of the desired specifications. Steelmaking fluxes are added to reduce the sulfur and phosphorus content of the metal, and the oxidation of silicon, carbon, manganese, phosphorus, and iron, provide the energy required to melt the scrap, form the slag, and attain the desired temperature inside the vessel. For more information on steel production, see Section 2.3.

Figure 3-3: Diagram of a Basic Oxygen Furnace Vessel



Source: Yildirim and Prezzi (2011)

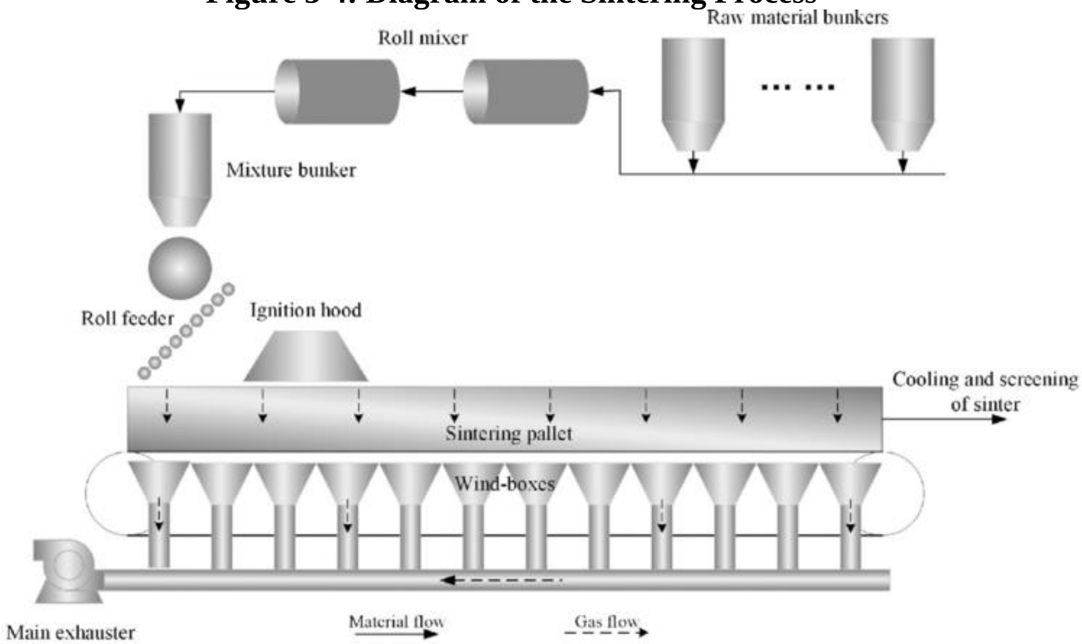
Emissions occur in the BOPF shop from hot metal transfer, desulfurization, charging, oxygen blow, and tapping. Emissions are captured by a hood system and routed to a wet scrubber or electrostatic precipitator (ESP) to remove PM. Incomplete capture of emissions from metallurgical processes inside the BOPF shop result in fugitive emissions, which exit through roof vents and other building openings. The major HAP emitted from the BOPF shop are manganese (Mn) and lead (Pb), in addition to smaller amounts of chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), selenium (Se), and other metal HAP.

3.2.2.3 Sinter Plants

Three II&S facilities include sinter plants: Gary Works, Burns Harbor Works, and Indiana Harbor Works. Sintering recovers the raw material value of many waste products generated at II&S facilities that would otherwise be landfilled or stockpiled. The sinter plant returns waste iron-bearing materials to the blast furnace and also provides part of the flux used in the iron-making process. Feed material includes iron ore fines, blast furnace dust, mill scale, and recycled fines from the sintering process.

The sintering machine accepts feed and conveys it down a moving strand. Near the feed end of the grate, the bed is ignited on the surface by gas burners and, as the mixture moves along on the traveling grate, air is pulled down through the mixture to burn the fuel by downdraft combustion; either coke oven gas or natural gas may be used for fuel to ignite the undersize coke or coal in the feed. As the grates move continuously over a series of windboxes toward the discharge end of the strand, the combustion front in the bed moves progressively downward. This creates sufficient heat and temperature to agglomerates the fine particles, forming a cake of porous clinker. The clinker is discharged to a breaker which reduces the clinker to smaller pieces. The sinter is then screened, cooled, and transferred to the blast furnace for use as feedstock. The sintering process is diagrammed in Figure 3-4.

Figure 3-4: Diagram of the Sintering Process



Source: Huang et al. (2018)

Emissions from the sintering process occur during raw material handling and mixing, through windbox exhaust, sinter machine discharge, and crushing, screening, cooling and storage of sinter. The most significant source of emissions is through the windbox exhaust, which is collected by an air capture system and directed to a baghouse or scrubber. Sinter plant windboxes are a potential source of organic HAP in addition to metal HAP and PM. HAP emissions from sinter plants primarily consist of Mn and Pb, but also include PAH, D/F, and volatile organic HAP along with smaller quantities of other metal HAP.

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 RIA, we present results for the final amendments to NESHAP Subpart FFFFF for II&S manufacturing facilities. Throughout this document, we focus the analysis on the final requirements that result in quantifiable compliance cost or emissions changes compared to the baseline.

EPA used a variety of sources and assumptions to develop emissions factors for blast furnace and BOPF shop fugitive emissions and emissions activity estimates for each facility.

This information includes stack testing data collected in 2011 and emission factors and activity estimates from a variety of sources. For a detailed description of the development of emissions estimates from these sources, see *Development of Emissions Estimates for Fugitive or Intermittent HAP Emissions Sources for an Example II&S Facility for input to the RTR Risk Assessment* (U.S. EPA, 2019c), available in the docket for the final rule (hereafter referred to as the Emissions Memo).20 For a discussion of the cost and emissions reduction estimates from fugitive sources and sinter plants, see the memorandums *Unmeasured Fugitive and Intermittent Particulate Emissions and Cost Impacts for Integrated Iron and Steel Facilities under 40 CFR Part 63, Subpart FFFFF* and *Maximum Achievable Control Technology Standard Calculations, Cost Impacts, and Beyond-the-Floor Cost Impacts for Integrated Iron and Steel Facilities under 40 CFR Part 63, Subpart FFFFF*, also available in the docket (hereafter referred to as the Technical Memos).

For the analysis, we calculate the cost and emissions impacts of the final NESHAP amendments from 2026 to 2035. The initial analysis year is 2026 as we assume the final action will be final and thus become effective during 2024, and the final rule allows 12 months for compliance with the fugitive emission requirements for BF/BOPF. Facilities must comply with fenceline monitoring requirements within two years after promulgation of the final rule, so costs for fenceline monitoring are assumed to begin in 2026. The final analysis year is 2035, which allows us to provide 10 years of potential regulatory impacts after the final amendments are assumed to fully take effect. We assume the number of facilities active in the source category remains constant during the analysis period. There is a lot of uncertainty in this assumption, as the II&S source category has significantly shrunk since EPA final the original NESHAP in 2001. Since 2001, the number of II&S facilities has fallen from 20 to 8, and the number of sinter plants has fallen from 9 to 3 (U.S. EPA, 2001). The most recent closure of a facility in the source category occurred in 2019. If the number of facilities in the source category continues to fall during the analysis period, it is likely the impacts projected in this RIA are overestimated.

20 Available at: https://www.regulations.gov/document/EPA-HQ-OAR-2002-0083-0956

3.3 Description of Regulatory Options

This RIA analyzes a less stringent alternative package of regulatory options in addition to the analyzing the final amendments to Subpart FFFFF. This section details the regulatory options examined for each emissions source covered by the rule. In addition to the emission limits discussed in each section, EPA is also finalizing additional compliance testing and monitoring, recordkeeping, and reporting requirements.

3.3.1 *Blast Furnaces and Basic Oxygen Process Furnaces*

3.3.1.1 Fugitive Emissions

EPA is finalizing standards to regulate five currently fugitive or intermittent particulate emissions sources: BF unplanned bleeder valve openings ("slips"), BF planned bleeder valve openings, BF and BOPF slag processing, handling, and storage, BF bell leaks, and beaching of iron from BFs. EPA is also finalizing updated requirements for fugitive emissions from two currently one regulated source: BOPF shops and BF casthouses.

For unplanned BF bleeder valve openings, EPA is finalizing specific work practices designed to limit emissions from slips. These work practices include:

- developing a work practice plan to minimize these events and submitting it to EPA for approval
- installing devices to continuously monitor material levels in the blast furnace, at a minimum of three locations, with alarms to inform operators of static conditions which increase likelihood of slips
- installing instruments on the blast furnace to monitor temperature and pressure to help determine when a slip has occurred
- and requiring raw material screening.

For planned BF bleeder valve openings, EPA is finalizing an 8 percent opacity limit but is not mandating specific work practices to achieve this limit. This allows facilities flexibility in determining how best to reduce emissions.

For BF bell leaks, EPA is finalizing specific work practices and a 10 percent opacity action level (which is slightly beyond-the-floor). The work practices require facilities to monitor the top of the blast furnace monthly to identify leaks, measure the opacity of the fugitive emissions if there is a leak, implement corrective action if the opacity action level is exceeded, and repair the bell seal within four months if the corrective action does not decrease the opacity below the action level. Facilities must also replace the small bell seal every six months or after five million tons of hot metal throughput, conduct monthly visible emissions testing for 15 minutes, and amend the metal throughput limit in the O&M plan as needed.

For BF/BOPF slag processing, handling and storage, EPA is finalizing a BTF 10 percent opacity limit. Facilities can control slag fugitive emissions by spraying water or using fogging as needed. EPA is also finalizing a MACT floor limit for BF iron beaching, along with work practice standards that require full or partial enclosures for beached iron and use of CO_2 to suppress fumes.

EPA is finalizing updated requirements for BOPF shop fugitive emissions, which have a current opacity limit of 20 percent. The final standards do not make changes to the opacity limit, but do include specific work practices for minimizing BOPF shop fugitive emissions. The work practices for BOPF shops include:

- setting a maximum hot iron pour/charge rate (pounds/second) for the first 20 seconds of hot metal pour
- setting a maximum furnace tilt angle during charging
- keeping all openings, except roof monitors, closed during tapping and material transfer events
- regularly inspecting BOPF shop structure for leaks
- optimizing positioning of hot metal ladles with respect to hood face and furnace mouth
- setting a maximum furnace tilt angle
- using a higher draft velocity to capture more fugitives at a given distance from the hood

- and monitoring opacity once per month from all openings for 30 minutes (which must include a tapping event).

This RIA also analyzes the less stringent regulatory option of not including work practice standards for BOPF shops and maintaining current opacity testing requirements for BF casthouses and BOPF shops. There are no costs associated with this option. EPA did not consider more stringent regulatory options for any of the fugitive emissions sources discussed in this section.

3.3.1.2 Other Regulatory Gaps

EPA identified two unregulated HAP emitted by BF and BOPF (HCl and THC) and three unregulated HAP emitted bby BF stoves and BOPF (HCl, THC, and D/F) and is finalizing a numerical MACT floor limit for each pollutant except D/F from BF stoves. It is projected that each facility can meet the MACT floor limit without installing additional controls or modifying work practices, so the only expected costs for these requirements are from additional compliance testing and monitoring, recordkeeping, and reporting. EPA did not identify a cost-effective BTF limit these pollutants, so we will not be evaluating a more stringent option for these pollutants as part of this RIA.

3.3.2 ***Sinter Plants***

3.3.2.1 Dioxins/Furans and Polycyclic Aromatic Hydrocarbons

EPA is finalizing a limit based on addition of ACI controls for D/F and PAH from sinter plant windboxes. There are currently no specific requirements for these pollutants, but the current VOC and oil content limits act as a surrogate standard for these HAP. Three II&S facilities have on-site sinter plants: Gary Works, Burns Harbor Works, and Indiana Harbor Works. Gary Works is owned by U.S. Steel and both Burns Harbor and Indiana Harbor Works are owned by Cleveland-Cliffs Inc. These plants currently control windbox emissions using a baghouse, Venturi scrubber, or a baghouse in combination with a dry scrubber. EPA anticipates that all three affected facilities could meet this limit by installing an activated carbon injection system to complement existing windbox controls.

This RIA also analyzes a less stringent regulatory option for D/F and PAH emissions from II&S sinter plants: setting a MACT limit. EPA anticipates these three facilities can meet the MACT floor limits for D/F and PAH without installing additional controls. The only associated costs would be for additional compliance testing.

3.3.2.2 Other Regulatory Gaps

EPA identified five unregulated HAP emitted by sinter plants (CS_2, COS, HCl, HF, and Hg) and is finalizing a numerical MACT floor limit for COS and HCl. It is projected that each facility can meet the MACT floor limit without installing additional controls or modifying work practices, so the only expected costs for these requirements are from additional compliance testing and monitoring, recordkeeping, and reporting. For Hg, EPA is finalizing a numerical BTF limit based on the addition of ACI controls on the sinter plant. It is projected that costs associated with the BTF limit are reflective of installation of ACI controls on the sinter plants, which are accounted for in the D/F and PAHs limits. CS_2 emissions are being addressed through setting a limit for COS, and HF emissions are being addressed through setting a limit for HCl.

3.3.3 *Fenceline Monitoring*

EPA is finalizing a fenceline monitoring requirement pursuant to CAA 112(d)(6). The fenceline monitoring requirement includes a work practice action level for Cr. If a monitor at a facility exceeds the action level for Cr, the facility must do a root-cause analysis and take corrective action to lower Cr emissions. EPA is also finalizing a sunset provision in the fenceline monitoring requirements: if facilities remain below the action level for two full years, they can terminate the fenceline monitoring as long as they continue to comply with all other rule requirements. Facilities must comply with fenceline monitoring requirements within two years following promulgation of the final rule (expected in late 2024). As part of this RIA, EPA is also analyzing a less stringent alternative regulatory option that does not include fenceline monitoring.

3.3.4 *Summary of Regulatory Alternatives*

This RIA analyzes three sets of regulatory alternatives in the emissions and engineering cost analysis presented in Sections 3.4 and 3.5: the final NESHAP amendments along with a set of less stringent and more stringent alternative regulatory options. The less stringent alternative regulatory options differ from the final amendments in three ways:

- there is a MACT floor limit based on the addition of ACI controls for D/F and PAH emissions from sinter plants rather than a BTF limit
- the opacity testing requirements for BF casthouses and BOPF shops are maintained at the current requirements (i.e., Final rule, 85 FR 42074, published 07/31/2023) with no added work practice standards for BOPF shops,
- there is no fenceline monitoring requirement.

3.4 Emissions Reduction Analysis

3.4.1 *Baseline Emissions Estimates*

The baseline emissions estimates for BF/BOPF fugitive emissions and sinter plant windbox D/F and PAH emissions are presented in Table 3-2 and Table 3-3 below. Estimates are presented both as emitted tons (or grams, in the case of D/F) per year and over the entire analysis period 2026–2035. 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. For BF/BOPF fugitive emissions, EPA estimated PM emissions and imputed $PM_{2.5}$ and HAP emissions by assuming each accounts for a constant share of PM (23 percent for $PM_{2.5}$ and 3.7 percent for HAP). The development of the baseline emissions estimates is described in the Emissions Memo.

Table 3-2: Baseline Emissions Estimates for II&S Blast Furnace and Basic Oxygen Process Furnace Fugitive Emissions[a]

	Pollutant	
Tons per Year	HAP	280
	PM	8,100
	$PM_{2.5}$	2,100
2026–2035	HAP	2,800
	PM	81,000
	$PM_{2.5}$	21,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-3: Baseline Emissions Estimates for II&S Sinter Plant Windboxes[a]

	Pollutant	
Grams per Year	D/F TEQ[b]	9.07
Tons per Year	PAH	6
2026–2035	D/F TEQ	90.1
	PAH	60

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

[b] TEQ stands for “toxic-equivalency.” TEQs are a weighted-measure based on each member of the dioxin and dioxin-like compounds category. See https://www.epa.gov/toxics-release-inventory-tri-program/dioxin-and-dioxin-compounds-toxic-equivalency-information for more information.

3.4.2 *Projected Emissions Reduction*

Projected emissions reductions for BF/BOPF fugitive emissions are presented in Table 3-4 below. The final NESHAP amendments are expected to reduce PM, $PM_{2.5}$, and HAP emissions at BF/BOPF roughly 30 percent relative to baseline. The projected emissions reduction from the stringent limit technology review for D/F and PAH emissions from sinter plant windboxes are presented in Table 3-5. The limits for D/F and PAH from sinter plant windboxes would control emissions about 90 percent relative to baseline. Table 3-6 shows the assumed level of control for each emissions source. In particular cases, facilities are assumed to already be implementing the required work practices for an emissions source and are not projected to reduce emissions. For additional information on the methods and assumption used to estimate emissions reductions, see the Emissions Memo and the Technical Memos.

Table 3-4: II&S Blast Furnace and Basic Oxygen Process Furnace Fugitive Emission Reductions[a]

		Less Stringent	Final
Tons per Year	HAP	39	64
	PM	1,100	1,900
	$PM_{2.5}$	240	470
2026–2035	HAP	390	640
	PM	11,000	19,000
	$PM_{2.5}$	2,400	4,700

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-5: II&S Sinter Plant Windbox Emission Reductions from Final Limit for D/F and PAH[a]

Grams per Year	D/F TEQ[b]	8.2
Tons per Year	PAH	5
2026–2035	D/F TEQ	66
	PAH	44

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] TEQ stands for "toxic-equivalency." TEQs are a weighted-measure based on each member of the dioxin and dioxin-like compounds category. See https://www.epa.gov/toxics-release-inventory-tri-program/dioxin-and-dioxin-compounds-toxic-equivalency-information for more information.

Table 3-6: Estimated Control from Fugitive Work Practice Standards and Windbox ACI

Source	% Control
BF Unplanned Openings	15-40
BF Planned Openings	0-50
BF Bell Leaks	25-50
BF Casthouse Fugitives	0
BOP Shop Fugitives	19-22
Beaching	0-50
Slag Handling	0-50
Sinter Plant Windbox D/F and PAH[a]	90

[a] This control percentage refers to the controls necessary to meet the limit for D/F and PAH, not the final MACT standard.

Table 3-7 shows estimated emissions reductions for each source of BF/BOPF fugitive or intermittent emissions. BOPF shop fugitives are by far the largest source of emissions reductions, accounting for more than 50 percent of the total. This explains the large difference in estimated reductions between the final option and the less stringent alternative option (the reductions of which can be obtained by eliminating the reductions from BF casthouse and BOPF shop fugitives. The less stringent and final options for sinter plant windboxes achieves no emission reductions because EPA projects all three facilities with sinter plants can meet the MACT floor limit for D/F and PAH without additional pollution controls.

Table 3-7: II&S Blast Furnace and Basic Oxygen Process Furnace Fugitive Emission Reductions by Source, Final Option (Tons per Year)[a]

Fugitive or Intermittent Emissions Source	PM	$PM_{2.5}$	HAP
BF Unplanned Openings	14	3.1	0.50
BF Planned Openings	11	2.5	0.41
BF Bell Leaks	830	190	31
BF Casthouse Fugitives	0	0	0
BOPF Shop Fugitives	790	230	25
Iron Beaching	0.094	0.028	0.0035
Slag Handling	220	43	7.4
Total	1,900	470	64

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.5 Engineering Cost Analysis

3.5.1 *Detailed Impacts Tables*

This section presents detailed cost tables for each section of the final amendments. 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 additional monitoring, recordkeeping, and reporting (MRR) (when necessary). Additional compliance testing for occurs initially and every 5 years thereafter, and is annualized over a 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/MRR costs, can be found in the Technical Memos. The bank prime rate was 7.00 percent at the time of the analysis but has since risen to 7.71 percent. All cost figures are in 2022$.

3.5.1.1 Fugitive or Intermittent Particulate Sources

Table 3-8 presents total capital investment and annualized costs for the final rule and less stringent alternative option for fugitive sources. The less stringent alternative option does not include work practice standards for BOPF shop fugitive emissions or change opacity testing requirements for BF casthouse or BOPF shop fugitive emissions but are otherwise identical the final option. The work practice standards for BOPF shop fugitive emissions and increased opacity testing requirements for BF casthouse and BOPF shop fugitive emissions account for approximately 23 percent of total capital investment, 28 percent of annual operation and maintenance (O&M) cost, and 59 percent of annualized testing/MRR cost for the final fugitive source standards. These estimates include the cost of labor and capital equipment necessary to implement the necessary work practices to meet the limits and monitor compliance.

Table 3-8: Summary of Total Capital Investment and Annual Costs per Year for Fugitive or Intermittent Particulate Sources (2022$)[a]

	Less Stringent	Final Rule
Total Capital Investment	$3,100,000	$4,700,000
Annual O&M	$1,900,000	$1,500,000
Annualized Capital	$1,200,000	$1,700,000
Annualized Testing/MRR	$230,000	$370,000
Total Annualized Cost	$3,300,000	$3,600,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-9 and Table 3-10 present the facility- and firm-level cost breakdown of the final and less stringent alternative option for fugitive sources. For the final option, estimated costs are roughly evenly split between Cleveland-Cliffs Inc. and U.S. Steel, with slightly more of the cost falling on Cleveland-Cliffs Inc., which owns five of eight II&S facilities.

Table 3-9: Summary of Total Capital Investment and Annual Costs per Year of the Final Option by Facility for Fugitive or Intermittent Particulate Sources (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Burns Harbor	$810,000	$130,000	$290,000
	Cleveland	$460,000	$260,000	$560,000
	Dearborn	$150,000	$68,000	$180,000
	Indiana Harbor	$890,000	$440,000	$940,000
	Middletown	$260,000	$68,000	$160,000
	Firm Total	$2,600,000	$970,000	$2,100,000
U.S. Steel	Mon Valley	$800,000	$280,000	$700,000
	Gary	$720,000	$68,000	$290,000
	Granite City	$640,000	$160,000	$430,000
	Firm Total	$2,200,000	$510,000	$1,400,000
Industry	Total	$4,700,000	$1,500,000	$3,600,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-10: Summary of Total Capital Investment and Annual Costs per Year of the Less Stringent Alternative by Facility for Fugitive or Intermittent Particulate Sources (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost[b]
Cleveland-Cliffs Inc.	Burns Harbor	$440,000	$370,000	$460,000
	Cleveland	$280,000	$260,000	$430,000
	Dearborn	$56,000	$63,000	$89,000
	Indiana Harbor	$670,000	$460,000	$820,000
	Middletown	$50,000	$190,000	$220,000
	Firm Total	$1,500,000	$1,300,000	$2,000,000
U.S. Steel	Mon Valley	$660,000	$290,000	$640,000
	Gary	$450,000	$58,000	$160,000
	Granite City	$500,000	$170,000	$380,000
	Firm Total	$1,600,000	$520,000	$1,200,000
Industry	Total	$3,100,000	$1,900,000	$3,200,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Includes annualized cost of compliance testing and MRR.

3.5.1.2 Sinter Plants

The final option for D/F and PAH from sinter plant windboxes sets a limit derived from technology review for D/F and PAH from sinter plant windboxes at II&S facilities. The estimates assume each facility will install an ACI system on stacks with existing PM controls. The Gary facility includes two stacks, which the Burns Harbor and Indiana Harbor facility have one stack each. The annualized costs assume a 20-year equipment life for each installed ACI system. EPA also analyzes a less stringent MACT floor limit for each pollutant. EPA estimates all three facilities with on-site sinter plants could meet the MACT floor without additional controls or changes to work practices, so this option would not reduce emissions. The only additional costs would be for compliance testing.

Table 3-11: Summary of Total Capital Investment and Annual Costs per Year of the Final Option for Sinter Plants D/F and PAH (2022$)[a] presents the facility- and firm-level costs associated with the limit for D/F and PAH from sinter plant windboxes at II&S facilities. Table 3-12 presents the facility- and firm-level costs associated with the less stringent MACT floor limit for D/F and PAH from sinter plant windboxes at II&S facilities.

Table 3-11: Summary of Total Capital Investment and Annual Costs per Year of the Final Option for Sinter Plants D/F and PAH (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost[b]
Cleveland-Cliffs Inc.	Burns Harbor	$240,000	$550,000	$600,000
	Indiana Harbor	$240,000	$550,000	$600,000
	Firm Total	$470,000	$1,100,000	$1,200,000
U.S. Steel	Gary	$470,000	$1,100,000	$1,200,000
	Firm Total	$470,000	$1,100,000	$1,200,000
Industry	Total	$950,000	$2,200,000	$2,400,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Includes annualized cost of compliance testing and MRR.

Table 3-12: Summary of Total Capital Investment and Annual Costs per Year of the Less Stringent Option for Sinter Plants D/F and PAH (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost[b]
Cleveland-Cliffs Inc.	Burns Harbor	$0	$0	$11,000
	Indiana Harbor	$0	$0	$11,000
	Firm Total	$0	$0	$22,000
U.S. Steel	Gary	$0	$0	$22,000
	Firm Total	$0	$0	$22,000
Industry	Total	$0	$0	$44,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Includes annualized cost of compliance testing and MRR.

3.5.1.3 Fenceline Monitoring

Table 3-13 presents the estimated costs for the final fenceline monitoring requirements by year. The costs include the capital cost of installing 4 monitors per facility in year one (2026and O&M, testing, and MRR costs for each year. Table 3-14 presents facility- and firm-level costs. EPA is also finalizing a sunset provision in the fenceline monitoring requirements: if facilities remain below the action level for two full years, they can terminate the fenceline monitoring as long as they continue to comply with all other rule requirements. Costs could decrease for particular facilities after two years of fenceline monitoring if they meet the requirements of the sunset provision. Facilities must comply with fenceline monitoring requirements within two years following promulgation of the final rule (expected in late 2024), so we assume costs are not incurred until 2026. Note that the less stringent alternative option analyzed in this RIA does not include fenceline monitoring.

Table 3-13: Costs by Year for the Final Fenceline Monitoring Requirements (2022$)[a]

Year	Capital	Annual O&M	Testing/MRR	Total
2026	$0	$0	$0	$0
2027	$800,000	$1,300,000	$0	$2,100,000
2028	$0	$1,300,000	$0	$1,300,000
2029	$0	$1,300,000	$0	$1,300,000
2030	$0	$1,300,000	$0	$1,300,000
2031	$0	$1,300,000	$0	$1,300,000
2032	$0	$1,300,000	$0	$1,300,000
2033	$0	$1,300,000	$0	$1,300,000
2034	$0	$1,300,000	$0	$1,300,000
2035	$0	$1,300,000	$0	$1,300,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

Table 3-14: Summary of Total Capital Investment and Annual Costs per Year of the Final Fenceline Monitoring Requirements (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost
Cleveland-Cliffs Inc.	Burns Harbor	$100,000	$160,000	$200,000
	Cleveland	$100,000	$160,000	$200,000
	Dearborn	$100,000	$160,000	$200,000
	Indiana Harbor	$100,000	$160,000	$200,000
	Middletown	$100,000	$160,000	$200,000
	Firm Total	$500,000	$820,000	$1,000,000
U.S. Steel	Mon Valley	$100,000	$160,000	$200,000
	Gary	$100,000	$160,000	$200,000
	Granite City	$100,000	$160,000	$200,000
	Firm Total	$300,000	$490,000	$610,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.

3.5.1.4 Summary of Facility-Level Costs

Table 3-15 and Table 3-16 present total facility- and firm-level costs for the final amendments and the less stringent alternative option. For the differences between the three sets of alternatives, see Section 3.3.4.

Table 3-15: Summary of Total Capital Investment and Annual Costs per Year of the Final Amendments (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost[b]
Cleveland-Cliffs Inc.	Burns Harbor	$1,100,000	$850,000	$1,100,000
	Cleveland	$560,000	$420,000	$770,000
	Dearborn	$250,000	$230,000	$380,000
	Indiana Harbor	$1,200,000	$1,200,000	$1,700,000
	Middletown	$360,000	$230,000	$370,000
	Firm Total	$3,500,000	$2,900,000	$4,400,000
U.S. Steel	Mon Valley	$900,000	$450,000	$900,000
	Gary	$1,300,000	$1,300,000	$1,700,000
	Granite City	$740,000	$320,000	$630,000
	Firm Total	$2,900,000	$2,100,000	$3,200,000
Industry	Total	$6,500,000	$5,000,000	$7,600,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Includes annualized cost of compliance testing and MRR.

Table 3-16: Summary of Total Capital Investment and Annual Costs per Year of the Less Stringent Alternative Options (2022$)[a]

Ultimate Parent Company	Facility	Total Capital Investment	Annual O&M	Annualized Cost[b]
Cleveland-Cliffs Inc.	Burns Harbor	$440,000	$370,000	$470,000
	Cleveland	$280,000	$260,000	$430,000
	Dearborn	$56,000	$63,000	$89,000
	Indiana Harbor	$670,000	$460,000	$830,000
	Middletown	$50,000	$190,000	$220,000
	Firm Total	$1,500,000	$1,300,000	$2,000,000
U.S. Steel	Mon Valley	$660,000	$290,000	$640,000
	Gary	$450,000	$58,000	$180,000
	Granite City	$500,000	$170,000	$380,000
	Firm Total	$1,600,000	$520,000	$1,200,000
Industry	Total	$3,100,000	$1,900,000	$3,200,000

[a] Totals may not sum due to independent rounding. Numbers rounded to two significant digits unless otherwise noted.
[b] Includes annualized cost of compliance testing and MRR.

3.5.2 *Summary Cost Tables for the Final Regulatory Options*

Table 3-17 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 final standards, we conservatively assume that all initial capital investment occurs in the first year of full implementation to represent a highest-cost scenario. Additional compliance testing occurs initially and once every five years thereafter to monitor compliance with the final MACT standards for BF/BOPF and sinter plants. Since compliance must occur within one year of the effective date of the final amendments, these costs are assumed to occur in 2026 (the first year of full implementation). Facilities must comply with fenceline monitoring requirements within two years following promulgation of the final rule (expected in early 2024), so we assume costs for that provision are not incurred until 2026. Table 3-18 presents total costs for each year discounted to 2024, 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 2024 is about $51 million ($6.0 million EAV) using a 3 percent social discount rate and about $41 million ($5.8 million EAV) using a 7 percent social discount rate from 2026–2035.

Table 3-17: Costs by Year for the Final Options (2022$)

Year	Capital	Annual O&M	Testing/MRR	Total
2026	$2,700,000	$1,300,000	$1,500,000	$5,500,000
2027	$2,800,000	$2,800,000	$0	$5,600,000
2028	$950,000	$5,000,000	$240,000	$6,200,000
2029	$0	$5,000,000	$60,000	$5,100,000
2030	$0	$5,000,000	$60,000	$5,100,000
2031	$0	$5,000,000	$1,600,000	$6,600,000
2032	$0	$5,000,000	$60,000	$5,100,000
2033	$0	$5,000,000	$240,000	$5,200,000
2034	$0	$5,000,000	$60,000	$5,100,000
2035	$0	$5,000,000	$60,000	$5,100,000

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

Table 3-18: Present-Value, Equivalent Annualized Value, and Discounted Costs for Final Options, 2026–2035 (million 2022$)

Year	Discount Rate (Discounted to 2024)	
	3%	7%
2026	$5.2	$4.8
2027	$5.1	$4.6
2028	$5.5	$4.7
2029	$4.4	$3.6
2030	$4.3	$3.4
2031	$5.4	$4.1
2032	$4.0	$3.0
2033	$4.0	$2.8
2034	$3.8	$2.6
2035	$3.7	$2.4
PV	**$45**	**$36**
EAV	**$5.3**	**$5.1**

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

4 HUMAN HEALTH BENEFITS OF EMISSIONS REDUCTIONS

4.1 Introduction

Implementing emissions controls required by the final NESHAP amendments is expected to reduce HAP emissions, including emissions of manganese (Mn), lead (Pb), arsenic (As), chromium/chromium VI (Cr/Cr+6), dioxins/furans (D/F), polycyclic aromatic hydrocarbons (PAH), and other HAP. The emission controls are also expected to reduce emissions of non-HAP pollutants, such as particulate matter (including $PM_{2.5}$). In this chapter, we provide the benefits analysis for the final NESHAP amendments. Data, resource, and methodological limitations prevented the EPA from monetizing some of the human health benefits from reduced exposure to the HAP directly targeted by this final rule. In addition, the potential benefits from reduced adverse ecosystem effects and improved visibility from the reduction in $PM_{2.5}$ emissions are also not monetized here. The EPA provides a qualitative discussion of HAP health effects later in this chapter.

In this section, we quantify the economic value of benefits of this final rule such as those associated with potential reductions in $PM_{2.5}$-related premature deaths and illnesses expected to occur as a result of implementing this rule. $PM_{2.5}$ emissions reductions occur as a result of implementing the HAP emission controls described earlier in the RIA.

The PV of the lower-bound benefits for the final option for this rule are $1.8 billion at a 3 percent discount rate and $1.2 billion at a 7 percent discount rate with EAVs of $200 and $170 million respectively. The PV of the upper-bound benefits for the final option for this rule are $3.7 billion at a 3 percent discount rate and $2.6 billion at a 7 percent discount rate with EAVs of $420 million and $340 million respectively. All estimates are reported in 2022 dollars.

4.2 Health Effects from Exposure to Hazardous Air Pollutants (HAP)

In the subsequent sections, we describe the health effects associated with the main HAP controlled by the final NESHAP amendments: manganese (Mn), lead (Pb), arsenic (As), and chromium (Cr). The final ruleis projected to reduce 110 tons HAP per year. With the data available, it was not possible to estimate the change in emissions of each individual HAP.

Quantifying and monetizing the economic value of reducing the risk of cancer and non-cancer effects is made difficult by: the lack of a central estimate of estimate of cancer and non-cancer risk and estimates of the value of an avoided case of cancer (fatal and non-fatal) and morbidity effects. Due to methodology and data limitations, we did not attempt to monetize the health benefits of reductions in HAP in this analysis. Instead, we are providing a qualitative discussion of the health effects associated with HAP emitted from sources subject to control under the final action.

4.2.1 *Manganese (Mn)*

Health effects in humans have been associated with both deficiencies and excess intakes of Mn. Chronic exposure to high levels of Mn by inhalation in humans results primarily in central nervous system effects. Visual reaction time, hand steadiness, and eye-hand coordination were affected in chronically-exposed workers. Manganism, characterized by feelings of weakness and lethargy, tremors, a masklike face, and psychological disturbances, may result from chronic exposure to higher levels. Impotence and loss of libido have been noted in male workers afflicted with manganism attributed to inhalation exposures. The EPA has classified Mn in Group D, not classifiable as to carcinogenicity in humans (U.S. EPA, 1995).

4.2.2 *Lead (Pb)*

Lead is associated with toxic effects in every organ system including adverse renal, cardiovascular, hematological, hepatic, reproductive, and developmental effects. However, the major target for Pb toxicity is the nervous system, both in adults and children. Long-term exposure of adults to Pb at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people and may also cause anemia. Children are more sensitive to the health effects of Pb than adults. No safe blood Pb level in children has been determined. At lower levels of exposure, Pb can affect a child's mental and physical growth. Fetuses exposed to Pb in the womb may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood also may slow mental development and cause lower intelligence later in childhood. There is evidence that these effects may persist beyond childhood

(ATSDR, 2020). EPA has determined that Pb is a probable human carcinogen (Group 2B) (U.S. EPA, 2004).

4.2.3 *Arsenic (As)*

Arsenic, a naturally occurring element, is found throughout the environment, and is considered toxic through the oral, inhalation and dermal routes. Acute (short-term) high-level inhalation exposure to As dust or fumes has resulted in gastrointestinal effects (nausea, diarrhea, abdominal pain, and gastrointestinal hemorrhage); central and peripheral nervous system disorders have occurred in workers acutely exposed to inorganic As. Chronic (long-term) inhalation exposure to inorganic As in humans is associated with irritation of the skin and mucous membranes. Chronic inhalation can also lead to conjunctivitis, irritation of the throat and respiratory tract, and perforation of the nasal septum (ATSDR, 2007).

Chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, hyperpigmentation, and liver or kidney damage in humans. Inorganic As exposure in humans, by the inhalation route, has been shown to be strongly associated with lung cancer, while ingestion of inorganic As in humans has been associated with a form of skin cancer and also to bladder, liver, and lung cancer. EPA has classified inorganic As as a Group A, human carcinogen (U.S. EPA, 1998a).

4.2.4 *Chromium (Cr)*

Chromium may be emitted in two forms, trivalent Cr (Cr+3) or hexavalent Cr (Cr+6). The respiratory tract is the major target organ for Cr+6 toxicity, for acute and chronic inhalation exposures. Shortness of breath, coughing, and wheezing have been reported from acute exposure to Cr+6, while perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory effects have been noted from chronic exposures. Further, animal studies have reported adverse reproductive effects from exposure to Cr+6. Human studies have clearly established the carcinogenic potential of Cr+6 by the inhalation route, resulting in an increased risk of lung cancer (ATSDR, 2012). EPA has classified Cr+6 as a Group A, human carcinogen (U.S. EPA, 1998b). Trivalent Cr is less toxic than Cr+6. The respiratory tract is also the major target organ for Cr+3 toxicity, similar to Cr+6. EPA has not classified Cr+3 with respect to carcinogenicity (U.S. EPA, 1998c).

4.2.5 *Dioxins/Furans (D/F)*

Dioxins and furans are a group of chemicals formed as unintentional byproducts of incomplete combustion. They are released to the environment during the combustion of fossil fuels and wood, and during the incineration of municipal and industrial wastes. Dioxins and furans are generally compared to 2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) as a reference (or index) chemical because it is relatively well-studied and the most toxic compound within the group. Out of all HAPs for which a health benchmark has been assigned, 2,3,7,8-TCDD is the most potent for both cancer and non-cancer hazard. 2,3,7,8-TCDD causes chloracne in humans, a severe acne-like condition. It is known to be a developmental toxicant in animals, causing skeletal deformities, kidney defects, and weakened immune responses in the offspring of animals exposed to 2,3,7,8-TCDD during pregnancy. Human studies have shown an association between 2,3,7,8-TCDD and soft-tissue sarcomas, lymphomas, and stomach carcinomas (ATSDR, 1998). EPA has classified 2,3,7,8- TCDD as a probable human carcinogen (Group B2) (U.S. EPA, 1985).

4.2.6 *Polycyclic Aromatic Hydrocarbons (PAH)*

PAH are a group of chemicals that are formed as byproducts of incomplete combustion. PAHs can be released to the environment during the burning of coal, oil, gas, wood, garbage, tobacco, or charbroiled meat. There are over 100 individual PAH compounds, and the health effects of these individual chemicals can vary (ATSDR, 1995). PAH are generally compared to benzo(a)pyrene as a single reference (or index) chemical as it is relatively well-studied and among the most toxic compound within the group. In animals, benzo[a]pyrene has been associated with adverse developmental, reproductive, and immunological effects. In humans, exposure to PAH mixtures is associated with adverse birth outcomes (including reduced birth weight, postnatal body weight, and head circumference), neurobehavioral effects, and decreased fertility. EPA has classified benzo(a)pyrene as carcinogenic to humans (U.S. EPA, 2017). In addition EPA has classified other PAH including, benz[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, and indeno[1,2,3-c,d]pyrene, as probable human carcinogens (Group B2).

4.2.7 *Other Air Toxics*

In addition to the compounds described above, other toxic compounds might be affected by this action. Other HAP that are emitted by II&S facilities that could be reduced by the final NESHAP amendments include copper (Cu), mercury (Hg), nickel (Ni), selenium (Se), carbonyl sulfide (COS), carbon disulfide (CS_2), hydrogen chloride, (HCl), and hydrogen fluoride (HF). Information regarding the health effects of those compounds can be found in the EPA's IRIS database.21

4.3 Approach to Estimating $PM_{2.5}$-related Human Health Benefits

This section summarizes the EPA's approach to estimating the incidence and economic value of the $PM_{2.5}$-related benefits estimated for this rule. The Regulatory Impact Analysis for the Final National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units Review of the Residual Risk and Technology Review (U.S. EPA, 2023a) and its corresponding Technical Support Document Estimating $PM_{2.5}$ -and Ozone –Attributable Health Benefits (TSD) (U.S. EPA, 2023b) provide a full discussion of the EPA's approach for quantifying the incidence and value of estimated air pollution-related health impacts. In these documents, the reader can find the rationale for selecting the health endpoints quantified; the demographic, health and economic data applied in the environmental Benefits Mapping and Analysis Program—Community Edition (BenMAP-CE); modeling assumptions; and the EPA's techniques for quantifying uncertainty.

Implementing this rule will affect the distribution of $PM_{2.5}$ concentrations throughout the U.S.; this includes locations both meeting and exceeding the NAAQS for PM. This RIA estimates avoided PM2.5-related health impacts that are distinct from those reported in the RIA for the PM NAAQS (U.S. EPA, 2022). The $PM_{2.5}$ NAAQS RIA provides an illustrative example of, but does not predict, the benefits and costs of strategies that States may choose to enact when implementing a revised NAAQS. Since these costs and benefits are illustrative, theycannot be added to the costs and benefits of policies that prescribe specific emission control measures.

21 U.S. EPA Integrated Risk Information System (IRIS) database is available at www.epa.gov/iris. Accessed March 30, 2022.

We estimate the quantity and economic value of air pollution-related effects by estimating counts of air pollution-attributable cases of adverse health outcomes, assigning dollar values to these counts, and assuming that each outcome is independent of one another. We construct these estimates by adapting primary research—specifically, air pollution epidemiology studies and economic value studies—from similar contexts. This approach is sometimes referred to as "benefits transfer." Below we describe the procedure we follow for: (1) selecting air pollution health endpoints to quantify; (2) calculating counts of air pollution effects using a health impact function; (3) specifying the health impact function with concentration-response parameters drawn from the epidemiological literature.

4.3.1 *Selecting Air Pollution Health Endpoints to Quantify*

As a first step in quantifying $PM_{2.5}$-related human health impacts, the EPA consults the *Integrated Science Assessment for Particulate Matter* (PM ISA) (U.S. EPA, 2019a) as summarized in the TSD for the Final Revised Cross State Air Pollution Rule Update (U.S. EPA, 2021b). This document synthesizes the toxicological, clinical, and epidemiological evidence to determine whether each pollutant is causally related to an array of adverse human health outcomes associated with either acute (i.e., hours or days-long) or chronic (i.e., years-long) exposure. For each outcome, the ISA reports this relationship to be causal, likely to be causal, suggestive of a causal relationship, inadequate to infer a causal relationship, or not likely to be a causal relationship.

The ISA for $PM_{2.5}$ found acute exposure to $PM_{2.5}$ to be causally related to cardiovascular effects and mortality (i.e., premature death), and respiratory effects as likely-to-be-causally related. The ISA identified cardiovascular effects and total mortality as being causally related to long-term exposure to $PM_{2.5}$ and respiratory effects as likely-to-be-causal; and the evidence was suggestive of a causal relationship for reproductive and developmental effects as well as cancer, mutagenicity, and genotoxicity.

The EPA estimates the incidence of air pollution effects for those health endpoints listed above where the ISA classified the impact as either causal or likely-to-be-causal. Table 4-1 reports the effects we quantified and those we did not quantify in this RIA. The list of benefit categories not quantified shown in the table is not exhaustive. Among the effects we quantified, we might not have been able to completely quantify either all human health impacts or economic values. The table below omits health effects associated with SO_2 and NO_2, and any welfare effects such as acidification and nutrient enrichment. These effects are described in the Technical Support Document "Estimating $PM_{2.5}$- and Ozone-Related Benefits", which details the approach EPA followed for selecting and quantifying PM-attributable effects (U.S. EPA, 2023b).

Table 4-1: Human Health Effects of $PM_{2.5}$ and whether they were Quantified and/or Monetized in this RIA

Category	Effect	Effect Quantified	Effect Monetized	More Information
Premature mortality from exposure to $PM_{2.5}$	Adult premature mortality from long-term exposure (age 65-99 or age 30-99)	✓	✓	PM ISA
	Infant mortality (age <1)	✓	✓	PM ISA
Nonfatal morbidity from exposure to $PM_{2.5}$	Heart attacks (age > 18)	✓	✓	PM ISA
	Hospital admissions—cardiovascular (ages 65-99)	✓	✓	PM ISA
	Emergency department visits— cardiovascular (age 0-99)	✓	✓	PM ISA
	Hospital admissions—respiratory (ages 0-18 and 65-99)	✓	✓	PM ISA
	Emergency room visits—respiratory (all ages)	✓	✓	PM ISA
	Cardiac arrest (ages 0-99; excludes initial hospital and/or emergency department visits)	✓	✓	PM ISA
	Stroke (ages 65-99)	✓	✓	PM ISA
	Asthma onset (ages 0-17)	✓	✓	PM ISA
	Asthma symptoms/exacerbation (6-17)	✓	✓	PM ISA
	Lung cancer (ages 30-99)	✓	✓	PM ISA
	Allergic rhinitis (hay fever) symptoms (ages 3-17)	✓	✓	PM ISA
	Lost work days (age 18-65)	✓	✓	PM ISA
	Minor restricted-activity days (age 18-65)	✓	✓	PM ISA
	Hospital admissions—Alzheimer's disease (ages 65-99)	✓	✓	PM ISA
	Hospital admissions—Parkinson's disease (ages 65-99)	✓	✓	PM ISA
	Other cardiovascular effects (e.g., other ages)	—	—	PM ISA
	Other respiratory effects (e.g., pulmonary function, non-asthma ER visits, non-bronchitis chronic diseases, other ages and populations)	—	—	PM ISA
	Other nervous system effects (e.g., autism, cognitive decline, dementia)	—	—	PM ISA
	Metabolic effects (e.g., diabetes)	—	—	PM ISA
	Reproductive and developmental effects (e.g., low birth weight, pre-term births, etc.)	—	—	PM ISA
	Cancer, mutagenicity, and genotoxicity effects	—	—	PM ISA

4.3.2 *Quantifying Cases of $PM_{2.5}$-Attributable Premature Death*

This section summarizes our approach to estimating the incidence and economic value of the $PM_{2.5}$-related ancillary co-benefits estimated for this rule. In December of 2022, EPA published the Regulatory Impact Analysis (RIA) for the final Particulate Matter National Ambient Air Quality Standards (U.S. EPA, 2024c). EPA quantified the PM-related benefits of this rule prior to publishing of the final PM NAAQS RIA. For this reason, the PM-related benefits reported in this RIA reflect methods consistent with an earlier version of the TSD (U.S. EPA, 2021b). Though the methodology employed in this RIA is largely consistent with the PM NAAQS RIA, here we estimate PM-attributable mortality using concentration-response parameters that differ from those applied in the PM NAAQS RIA. Specifically, we estimate PM-attributable deaths using concentration-response parameters from the Di et al. (2017) and Turner et al. (2016) long-term exposure studies of the Medicare and American Cancer Society cohorts, respectively. The user manual for the environmental Benefits Mapping and Analysis Program-Community Edition (BenMAP-CE) program22 separately details EPA's approach for quantifying and monetizing PM-attributable effects in the BenMAP-CE program. In these documents the reader can find the rationale for selecting health endpoints to quantify; the demographic, health and economic data we apply within BenMAP-CE; modeling assumptions; and our techniques for quantifying uncertainty.

The PM ISA, which was reviewed by the Clean Air Scientific Advisory Committee of the EPA's Science Advisory Board (U.S. EPA-SAB-CASAC, 2019), concluded that there is a causal relationship between mortality and both long-term and short-term exposure to $PM_{2.5}$ based on the body of scientific evidence. The PM ISA also concluded that the scientific literature supports the use of a no-threshold log-linear model to portray the PM-mortality concentration-response relationship while recognizing potential uncertainty about the exact shape of the concentration-response function. The PM ISA identified epidemiologic studies that examined the potential for a population-level threshold to exist in the concentration-response relationship. Based on such studies, the ISA concluded that "…the evidence from recent studies reduce uncertainties related to potential co-pollutant confounding and continues to provide strong support for a linear, no-threshold concentration-response relationship" (U.S. EPA, 2019a). Consistent with this evidence, the EPA historically has estimated health impacts above and below the prevailing NAAQS.23

22 BenMAP-CE Manual and Appendices, 2022. https://www.epa.gov/benmap/benmap-ce-manual-and-appendices

23 The Federal Register Notice for the 2012 PM NAAQS notes that "[i]n reaching her final decision on the appropriate annual standard level to set, the Administrator is mindful that the CAA does not require that primary

Following this approach, we report the estimated $PM_{2.5}$-related benefits (in terms of both health impacts and monetized values) calculated using a log-linear concentration-response function that quantifies risk from the full range of simulated $PM_{2.5}$ exposures (U.S. EPA, 2021b). As noted in the preamble to the 2020 PM NAAQS final rule, the "health effects can occur over the entire distributions of ambient $PM_{2.5}$ concentrations evaluated, and epidemiological studies do not identify a population-level threshold below which it can be concluded with confidence that PM-associated health effects do not occur."24 In general, we are more confident in the size of the risks we estimate from simulated $PM_{2.5}$ concentrations that coincide with the bulk of the observed PM concentrations in the epidemiological studies that are used to estimate the benefits. Likewise, we are less confident in the risk we estimate from simulated $PM_{2.5}$ concentrations that fall below the bulk of the observed data in these studies (U.S. EPA, 2021b). As described further below, we lacked the air quality modeling simulations to perform such an analysis for this final rule and thus report the total number of avoided $PM_{2.5}$-related premature deaths using the traditional log-linear no-threshold model noted above.

4.3.3 *Economic Valuation*

After quantifying the change in adverse health impacts, we estimate the economic value of these avoided impacts. Reductions in ambient concentrations of air pollution generally lower the risk of future adverse health effects by a small amount for a large population. Therefore, the appropriate economic measure is willingness to pay (WTP) for changes in risk of a health effect. For some health effects, such as hospital admissions, WTP estimates are generally not available, so we use the cost of treating or mitigating the effect. These cost-of-illness (COI) estimates generally (although not necessarily in every case) understate the true value of reductions in risk of a health effect. They tend to reflect the direct expenditures related to treatment but not the

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standards be set at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health,
including the health of at-risk populations, with an adequate margin of safety. On balance, the Administrator
concludes that an annual standard level of 12 ug/m3 would be requisite to protect the public health with an
adequate margin of safety from effects associated with long- and short-term $PM_{2.5}$ exposures, while still
recognizing that uncertainties remain in the scientific information."

24 https://www.govinfo.gov/content/pkg/FR-2020-12-18/pdf/2020-27125.pdf

value of avoided pain and suffering from the health effect. The unit values applied in this analysis are provided in Section 5.1 of the TSD for the Revised Cross State Update rule (U.S. EPA, 2021b).

Avoided premature deaths account for 98 percent of monetized PM-related benefits. The economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. The value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economics and public policy analysis community. Following the advice of the SAB's Environmental Economics Advisory Committee (SAB-EEAC), the EPA currently uses the value of statistical life (VSL) approach in calculating estimates of mortality benefits, because we believe this calculation provides the most reasonable single estimate of an individual's WTP for reductions in mortality risk (U.S. EPA-SAB, 2000). The VSL approach is a summary measure for the value of small changes in mortality risk experienced by a large number of people.

The EPA continues work to update its guidance on valuing mortality risk reductions and consulted several times with the SAB-EEAC on the issue. Until updated guidance is available, the EPA determined that a single, peer-reviewed estimate applied consistently best reflects the SAB-EEAC advice it has received. Therefore, the EPA applies the VSL that was vetted and endorsed by the SAB in the *Guidelines for Preparing Economic Analyses* while the EPA continues its efforts to update its guidance on this issue (U.S. EPA, 2016). This approach calculates a mean value across VSL estimates derived from 26 labor market and contingent valuation studies published between 1974 and 1991. The mean VSL across these studies is $6.3 million (2000$).25

The EPA is committed to using scientifically sound, appropriately reviewed evidence in valuing changes in the risk of premature death and continues to engage with the SAB to identify scientifically sound approaches to update its mortality risk valuation estimates. Most recently, the Agency final new meta-analytic approaches for updating its estimates which were subsequently reviewed by the SAB-EEAC. The EPA is taking the SAB's formal recommendations under advisement (U.S. EPA-SAB, 2017).

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25 In 1990$, this base VSL is $4.8 million. In 2016$, this base VSL is $10.7 million.

4.4 Monetized $PM_{2.5}$ Benefits

4.4.1 *Benefit-per-Ton Estimates*

The EPA did not conduct air quality modeling for this rule. Rather, we quantified the value of reducing PM concentrations using a "benefit-per-ton" approach, due to the relatively small number of facilities and the fact that these facilities are located in a discrete location. These BPT estimates provide the total monetized human health benefits (the sum of premature mortality and premature morbidity) of reducing one ton of $PM_{2.5}$ (or $PM_{2.5}$ precursor such as NO_x or SO_2) from a specified source. Specifically, in this analysis, we multiplied the estimates from the "II&S Facilities" sector, which are large enough to provide substantial benefits, by the corresponding emission reductions. The method used to derive these estimates is described in the BPT Technical Support Document (BPT TSD) on Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5,}$ $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors and its precursors from 21 sectors (U.S. EPA, 2023d). As noted above, we were unable to quantify the value of changes in exposure to HAP, CO, NO_2.

As noted below in the characterization of uncertainty, all BPT estimates have inherent limitations. Specifically, all national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to rulemaking, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. Given use of a regional, sector specific BPT and the small changes in emissions considered in this rulemaking, the difference in the quantified health benefits that result from the BPT approach compared with if EPA had used a full-form air quality model should be minimal.

The EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project", began in 2017, and the final report became available in 2019 (Industrial Economics, Inc., 2019). The Agency's goal was to create a methodology by which investigators could better understand the suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis, including the extent to which reduced form models may over- or under-estimate benefits (compared to full-scale modeling) under different scenarios and air quality concentrations. The EPA Science Advisory Board (SAB) convened a panel to review this report.[26] In particular, the SAB assessed: the techniques the Agency used to appraise these tools; the Agency's approach for depicting the results of reduced-form tools; and steps the Agency might take for improving the reliability of reduced-form techniques for use in future Regulatory Impact Analyses.

The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project27. Results of this project found that total $PM_{2.5}$ BPT values were within approximately 10 percent of the health benefits calculated from full-form air quality modeling when analyzing the Pulp and Paper sector. The ratios for individual species varied, and the report found that the ratio for the directly emitted $PM_{2.5}$ for the pulp and paper sector was 0.7 for the BPT approach compared to 1.0 for full air quality modeling combined with BenMAP. This provides some initial understanding of the uncertainty which is associated with using the BPT approach instead of full air quality modeling.

4.4.2 *$PM_{2.5}$ Benefits Results*

Table 4-2 lists the estimated $PM_{2.5}$-related benefits per ton applied in this national level analysis. Benefits are estimated using two concentration-response parameters for quantifying PM-attributable mortality and discounted at 3 and 7 percent for a 2022 currency year. For all estimates, we summarize the monetized $PM_{2.5}$-related health benefits using discount rates of 3 percent and 7 percent for the 10-year analysis period of this rule discounted back to 2024 rounded to 2 significant figures as presented in Table 4-3. The PV of the lower-bound estimated benefits for the final rule are $1.8 billion at a 3 percent discount rate and $1.3 billion at a 7 percent discount rate with EAVs of $200 million and $170 million respectively. The PV of the upper-bound benefits for the final rule are $3.7billion at a 3 percent discount rate and $2.6 billion at a 7 percent discount rate with EAVs of $420 million and $350 million respectively. All

26 85 FR 23823. April 29, 2020.
27 Available here: https://www.epa.gov/benmap/reduced-form-evaluation-project-report.

estimates are reported in 2022 dollars. Undiscounted benefits are presented by year for the final and less stringent alternative options in Table 4-4 and Table 4-5. For the full set of underlying calculations see the "Integrated Iron and Steel Benefits workbook", available in the docket for the proposal.

Table 4-2: II&S Benefit per Ton Estimates of $PM_{2.5}$-Attributable Premature Mortality and Illness for the Final Option, 2025-2035 ($2022)

	Discount Rate					
Year	**3 Percent**			**7 Percent**		
2025	$414,202	and	$885,807	$372,556	and	$798,014
2030	$447,968	and	$927,452	$402,946	and	$834,031
2035	$501,995	and	$1,012,993	$451,345	and	$911,694

Note: The standard reporting convention for EPA benefits is to round all results to two significant figures. Here, we report all significant figures so that readers may reproduce the results reported below. The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

Table 4-3: II&S Benefit Estimates of $PM_{2.5}$-Attributable Premature Mortality and Illness for the Proposal (million 2022$)[a,b,c]

	Less Stringent Regulatory Option						Final Regulatory Option					
	Discount Rate						Discount Rate					
	3 Percent			7 Percent			3 Percent			7 Percent		
PV	900	and	1,900	640	and	1,300	1,800	and	3,700	1,300	and	2,600
EAV	100	and	210	85	and	180	200	and	420	170	and	350

[a] Discounted to 2024
[b] Rounded to 2 significant figures.
[c] The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

Table 4-4: Undiscounted Monetized Benefits Estimates of $PM_{2.5}$-Attributable Premature Mortality and Illness for the Final Option (million 2022$), 2026–2035[a,b]

Year	3%	7%
2026	$180 and $380	$160 and $340
2027	$200 and $420	$180 and $380
2028	$210 and $440	$190 and $390
2029	$210 and $440	$190 and $390
2030	$210 and $440	$190 and $390
2031	$210 and $440	$190 and $390
2032	$210 and $440	$190 and $390
2033	$240 and $480	$210 and $430
2034	$240 and $480	$210 and $430
2035	$240 and $480	$210 and $430

[a] Rounded to 2 significant figures
[b] The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

Table 4-5: Undiscounted Monetized Benefits Estimates of $PM_{2.5}$-Attributable Premature Mortality and Illness for the Less Stringent Alternative Option (million 2022$), 2026–2035[a,b]

Year	3%	7%
2026	$80 and $170	$72 and $150
2027	$99 and $210	$89 and $190
2028	$110 and $220	$97 and $200
2029	$110 and $220	$97 and $200
2030	$110 and $220	$97 and $200
2031	$110 and $220	$97 and $200
2032	$110 and $220	$97 and $200
2033	$120 and $240	$110 and $220
2034	$120 and $240	$110 and $220
2035	$120 and $240	$110 and $220

[a] Rounded to 2 significant figures
[b] The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

4.4.3 *Characterization of Uncertainty in the Monetized $PM_{2.5}$ Benefits*

In any complex analysis using estimated parameters and inputs from a variety of models, there are likely to be many sources of uncertainty. This analysis is no exception. This analysis includes many data sources as inputs, including emission inventories, air quality data from models (with their associated parameters and inputs), population data, population estimates, health effect estimates from epidemiology studies, economic data for monetizing benefits, and assumptions regarding the future state of the world (i.e., regulations, technology, and human behavior). Each of these inputs are uncertain and generate uncertainty in the benefits estimate.

When the uncertainties from each stage of the analysis are compounded, even small uncertainties can have large effects on the total quantified benefits. Therefore, the estimates of annual benefits should be viewed as representative of the magnitude of benefits expected, rather than the actual benefits that would occur every year.

5 ECONOMIC IMPACT ANALYSIS AND DISTRIBUTIONAL ASSESSMENTS

5.1 Introduction

The final NESHAP amendments are projected to result in environmental control expenditures and work practice adjustments to comply with the rule. The national-level compliance cost analysis in Section 3.5 does not speak directly to potential economic and distributional impacts of the final rule, which may be important consequences of the action. This section is directed towards complementing the compliance cost analysis and includes an analysis of potential firm-level impacts of regulatory costs and a discussion of potential employment and small entity impacts.

5.2 Economic Impact Analysis

Although facility-specific economic impacts (production changes or closures, for example) cannot be estimated by this analysis, the EPA conducted a screening analysis of compliance costs compared to the revenue of firms owning II&S facilities. The EPA often performs a partial equilibrium analysis to estimate impacts on producers and consumers of the products or services provided by the regulated firms. This type of economic analysis estimates impacts on a single affected industry or several affected industries, and all impacts of this rule on industries outside of those affected are assumed to be zero or inconsequential (U.S. EPA, 2016).

If the compliance costs, which are key inputs to an economic impact analysis, are small relative to the receipts of the affected industries, then the impact analysis may consist of a calculation of annual (or annualized) costs as a percent of sales for affected parent companies. This type of analysis is often applied when a partial equilibrium or more complex economic impact analysis approach is deemed unnecessary given the expected size of the impacts. The annualized cost per sales for a company represents the maximum price increase in the affected product or service needed for the company to completely recover the annualized costs imposed by the regulation. We conducted a cost-to-sales analysis to estimate the economic impacts of this proposal, given that the EAV of the compliance costs are $5.1 million using a 7 percent discount rate and $5.3 million using a 3 percent discount rate in 2022 dollars, which is small relative to the revenues of the steel industry.

The EPA prefers a "sales test" as the impact methodology in economic impact analyses as opposed to a "profits test", in which annualized compliance costs are calculated as a share of profits.28 This is consistent with guidance published by the U.S. Small Business Administration (SBA) Office of Advocacy, which suggests that cost as a percentage of total revenues is a metric for evaluating cost impacts on small entities relative to large entities.29 This is because revenues or sales data are commonly available for entities impacted by the EPA regulations and profits data are often private or tend to misrepresent true profits earned by firms after undertaking accounting and tax considerations.

While a "sales test" can provide some insight as to the economic impact of an action such as this one, it assumes that the impacts of a rule are solely incident on a directly affected firm (therefore, no impact to consumers of an affected product), or solely incident on consumers of output directly affected by this action (therefore, no impact to companies that are producers of affected product). Thus, an analysis such as this one is best viewed as providing insight on the polar examples of economic impacts: maximum impact to either directly affected companies or their consumers. A "sales test" analysis does not consider shifts in supply and demand curves to reflect intermediate economic outcomes such as output adjustments in response to increased costs.

As discussed in Chapter 2, only two firms own the eight remaining II&S manufacturing facilities in the United States: Cleveland-Cliffs Inc. (Burns Harbor, Cleveland, Dearborn, Indiana Harbor, and Middletown Works) and U.S. Steel (Gary, Granite City, and Mon Valley Works). Both firms reported sales greater than $20 billion in 2021 (see Table 5-1).

Table 5-1: II&S 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 2021 and Cleveland-Cliffs Inc. Form 10-K 2021

28 More information on sales and profit tests as used in analyses done by U.S. EPA can be found in the Final Guidance for EPA Rulewriters: Regulatory Flexibility Act as Amended by the Small Business Regulatory Enforcement Fairness Act, November 2006, pp. 32-33.

29 U.S. SBA, Office of Advocacy. 2010. A Guide for Government Agencies, How to Comply with the Regulatory Flexibility Act, Implementing the President's Small Business Agenda and Executive Order 13272.

Table 5-2 and Table 5-3 present total annualized cost and total capital investment relative to sales for each set of regulatory alternatives. Firm revenues have been converted to 2022 dollars to accord with the dollar-year of the cost estimates. 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 0.02 percent). These costs include the costs of BF/BOPF fugitive emission work practices and monitoring, the costs of installing ACI at sinter plants to meet the limit for D/F and furans, the costs of fenceline monitoring, and the cost of additional compliance testing and monitoring, recordkeeping, and reporting. Based on this estimate, the maximum necessary price increase caused by the final regulation is small relative to the size of the firms that own facilities in the source category, and the potential economic impacts of the final rule are likely to be small.

Table 5-2: Total Annualized Cost-to-Sales Ratios for II&S 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	$2.0	0.0092%
	Final		$4.4	0.020%
U.S. Steel	Less Stringent	$21,562	$1.2	0.0056%
	Final		$3.2	0.015%

Table 5-3: Total Capital Investment-to-Sales Ratios for II&S Facility Owners by Regulatory Alternative

Ultimate Parent Company	Regulatory Alternative	2021 Revenue (million 2022$)	Total Capital Investment (million 2022$)	TCI-Sales Ratio
Cleveland-Cliffs Inc.	Less Stringent	$21,742	$1.5	0.0069%
	Final		$3.5	0.016%
U.S. Steel	Less Stringent	$21,562	$1.6	0.0074%
	Final		$2.9	0.013%

5.3 Employment Impacts 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 potential impacts on II&S manufacturing firms discussed in Section 5.2 , the final requirements are unlikely to cause large shifts in steel production and prices. As a result, demand for labor employed in steel production activities and associated industries is unlikely to see large changes but 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 devices as well as changes in employment due to quantity effects in directly-regulated sectors and sectors that consume steel produced by integrated manufacturing facilities. For this proposal, however, we do not have the data and analysis available to quantify these potential labor impacts.

5.4 Small Business Impact Analysis

To determine the possible impacts of the final NESHAP amendments on small businesses, parent companies producing iron and steel in integrated facilities are categorized as small or large using the SBA's general size standards definitions. For NAICS 331110 (Iron and Steel Mills and Ferroalloy Manufacturing), these guidelines indicate a small business employs 1,500 or fewer workers.30 Only two ultimate parent companies, Cleveland-Cliffs Inc. and U.S. Steel, own II&S manufacturing facilities in the United States. Based on the SBA definition and the company employment shown in Table 5-1, this industry has no small businesses.

30 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.

6 COMPARISON OF BENEFITS AND COSTS

In this chapter, we present a comparison of the benefits and costs of this final action. As explained in the previous chapters, all costs and benefits outlined in this RIA are estimated as the change from the baseline, which reflects the requirements already promulgated, and does not take into account other ongoing rulemakings, which may impose similar or identical requirements on a subset of facilities affected by this rule (thus reducing the additional economic impact of complying with this rule). As stated earlier in this RIA, there is no monetized estimate of the benefits for the HAP emission reductions expected to occur as a result of this final action. Further, the monetized benefits associated with $PM_{2.5}$ only include health benefits associated with reduced premature mortality and morbidity associated with exposure to $PM_{2.5}$, and do not include other health and environmental impacts associated with reduced PM emissions, such as ecosystem effects and reduced visibility. EPA expects these benefits are positive, and as a result the net benefits presented in this section are likely understated.

6.1 Results

As part of fulfilling analytical guidance with respect to E.O. 12866, EPA presents estimates of the present value (PV) of the benefits and costs over the period 2026 to 2035. To calculate the present value of the social net benefits of the final action, annual benefits and costs are in 2022 dollars and are discounted to 2024 at 3 percent and 7 percent discount rates as directed by OMB's Circular A-4. The EPA also presents the equivalent annualized value (EAV), which represents a flow of constant annual values that would yield a sum equivalent to the PV. The EAV represents the value of a typical cost or benefit for each year of the analysis, consistent with the estimate of the PV, in contrast to year-specific estimates.

Table 6-1 presents a summary of the monetized benefits, compliance costs, and net benefits of the final NESHAP amendments and the less stringent alternative regulatory options, in terms of present value (PV) and equivalent annualized value (EAV). Table 6-1 lists benefits using two alternative concentration-response from Di et al. (2016) and Turner et al. (2017).

Table 6-1: Summary of Monetized Benefits, Compliance Costs, Net Benefits, and Non-Monetized Benefits PV/EAV, 2026–2035 (million 2022$, discounted to 2024)[a,b]

	Final Rule		Less Stringent Alternative	
3%	PV	EAV	PV	EAV
Monetized Health Benefits	$1,800 and $3,700	$200 and $420	$890 and $1,800	$100 and $210
Compliance Costs	$45	$5.3	$21	$2.5
Net Benefits	$1,800 and $3,700	$190 and $410	$870 and $1,800	$98 and $210
7%				
Monetized Health Benefits	$1,200 and $2,600	$170 and $340	$630 and $1,300	$83 and $170
Compliance Costs	$36	$5.1	$17	$2.4
Net Benefits	$1,200 and $2,600	$160 and $330	$610 and $1,300	$81 and $170
Non-monetized Benefits	64 tpy HAP, 8.2 grams/year D/F, 5 tpy PAH, 47lbs/yr Hg		39 tpy HAP	
	Health effects of reduced exposure to HAP[c],D/F, PAH, and Hg			
	Non-health benefits from reducing 18,000 tons of PM, of which 4,700 tons is $PM_{2.5}$, from 2026–2035			
	Benefits from reducing HCl, HF, Hg, D/F TEQ, COS, and CS2			
	Reduced Ecosystem/Vegetation Effects			

[a] Rounded to two significant figures. Rows may not appear to add correctly due to rounding.

[b] Monetized benefits include health benefits associated with reductions in $PM_{2.5}$ emissions. The health benefits are associated with several point estimates and are presented at real discount rates of 3 and 7 percent. The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent. Benefits from HAP reductions remain unmonetized and are thus not reflected in the table. Rows may not appear to add correctly due to rounding.

[c] For details on HAP health effects associated with the rule, see Section 4.2.

Given these results, the EPA expects that implementation of the final NESHAP amendments, based solely on an economic efficiency criterion, will provide society with a substantial net gain in welfare, notwithstanding the set of health and environmental benefits and other impacts we were unable to quantify such as monetization of benefits from HAP emission reductions. Further quantification of directly-emitted $PM_{2.5}$ and HAP would increase the estimated net benefits of the final action. Undiscounted net benefits of the final amendments are presented in Table 6-2 and Table 6-3 below.

Table 6-2: Undiscounted Net Benefits Estimates for the Final Option (million 2022$), 2026–2035[a,b]

Year	3%	7%
2026	$170 and $370	$150 and $330
2027	$190 and $410	$170 and $370
2028	$200 and $430	$180 and $380
2029	$200 and $430	$180 and $380
2030	$200 and $430	$180 and $380
2031	$200 and $430	$180 and $380
2032	$200 and $430	$180 and $380
2033	$230 and $470	$200 and $420
2034	$230 and $470	$200 and $420
2035	$230 and $470	$200 and $420

[a] Rounded to 2 significant figures
[b] The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

Table 6-3: Undiscounted Net Benefits Estimates for the Less Stringent Alternative Option (million 2022$), 2026–2035[a]

Year	3%	7%
2026	$74 and $160	$66 and $140
2027	$97 and $210	$87 and $190
2028	$110 and $220	$95 and $200
2029	$110 and $220	$95 and $200
2030	$110 and $220	$95 and $200
2031	$110 and $220	$94 and $200
2032	$110 and $220	$95 and $200
2033	$120 and $240	$110 and $220
2034	$120 and $240	$110 and $220
2035	$120 and $240	$110 and $220

[a] Rounded to 2 significant figures
[b] The monetized health benefits are quantified using two alternative concentration-response relationships from the Di et al. (2016) and Turner et al. (2017) studies and presented at real discount rates of 3 and 7 percent.

6.2 Uncertainties and Limitations

Throughout the RIA, we considered a number of sources of uncertainty, both quantitatively and qualitatively, regarding the benefits, and costs of the final 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. Multiple facilities have idled or closed over the last several years, and if this trend were to continue then the costs and emissions impacts of the proposal may be overestimated. Unexpected facility closure or idling affects the number of facilities subject to the final amendments. We also assume 100 percent compliance with these final 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 final rules in the future.

- **Years of analysis**: The years of the cost analysis are 2026, to represent the first-year facilities are fully compliant with the final amendments, through 2035, to present 10 years of potential regulatory impacts, as discussed in Chapter 3. Extending the analysis beyond 2035 would introduce substantial and increasing uncertainties in the projected impacts of the final regulations.

- **Compliance Costs**: There is uncertainty associated with the costs required to install and operate the equipment and perform the work practices necessary to meet the final 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 final action may be underestimated. There is also uncertainty over which facilities will require fenceline monitoring after the sunset provision takes effect after two years; to the extent some facilities become exempt from these requirements, the costs presented in this RIA are overstated. Finally, the compliance costs presented above do not take into account whether other ongoing rulemakings (including those affecting lime manufacturing, coke ovens, taconite iron ore processing, and electric arc furnace sources) impose identical or similar requirements. If these other rulemakings impose similar emissions control technology requirements, the marginal compliance cost of this rulemaking would be substantially lower than the compliance costs presented above.

- **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, the emissions reductions (and therefore benefits) associated with the final amendments could be over or underestimated.
- **BPT estimates:** All national-average BPT estimates reflect the geographic distribution of the modeled emissions, which may not exactly match the emission reductions that would occur due to the action, and they may not reflect local variability in population density, meteorology, exposure, baseline health incidence rates, or other local factors for any specific location. Recently, the EPA systematically compared the changes in benefits, and concentrations where available, from its BPT technique and other reduced-form techniques to the changes in benefits and concentrations derived from full-form photochemical model representation of a few different specific emissions scenarios. Reduced form tools are less complex than the full air quality modeling, requiring less agency resources and time. That work, in which we also explore other reduced form models is referred to as the "Reduced Form Tool Evaluation Project" (Project), began in 2017, and the initial results were available at the end of 2018. The Agency's goal was to better understand the

suitability of alternative reduced-form air quality modeling techniques for estimating the health impacts of criteria pollutant emissions changes in the EPA's benefit-cost analysis. The EPA continues to work to develop refined reduced-form approaches for estimating benefits. The scenario-specific emission inputs developed for this project are currently available online. The study design and methodology are described in the final report summarizing the results of the project, available at <https://www.epa.gov/sites/production/files/2019-11/documents/rft_combined_report_10.31.19_final.pdf>.

- **Non-monetized benefits:** Numerous categories of health and welfare benefits are not quantified and monetized in this RIA. These unquantified benefits, including benefits from reductions in emissions of pollutants such as HAP which are to be reduced by this final action, are described in detail in Chapter 4 of this RIA.

- **PM health impacts**: In this RIA, we quantify an array of adverse health impacts attributable to emissions of PM. The Integrated Science Assessment for Particulate Matter (U.S. EPA, 2019) identifies the human health effects associated with ambient particles, which include premature death and a variety of illnesses associated with acute and chronic exposures. As described in the TSD "Estimating $PM_{2.5}$ and Ozone-Attributable Health Benefits" (U.S. EPA, 2023b), EPA did not quantify endpoints classified in the ISA as being "less than causally" related to $PM_{2.5}$.

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