Technical Support Document (TSD)
for the Proposed Rule

Docket ID No. EPA-HQ-OAR-2021-0668

Non-EGU Sectors TSD

U.S. Environmental Protection Agency
Office of Air and Radiation
December 2021

Note: EPA Originally posted this document on March 11, 2022. This document, posted on March 14, 2022, corrects an inadvertent error with the figure on page 9, part of which was not visible on the page.

Table of Contents

1 Introduction/Purpose

The purpose of this Technical Support Document (TSD) is to discuss the basis for the proposed emissions limits and monitoring, recordkeeping, and reporting requirements for the following unit types for sources in non-EGU industries: engines in Pipeline Transportation of Natural Gas sources; kilns in Cement and Cement Product Manufacturing sources; boilers and furnaces in Iron and Steel Mills and Ferroalloy Manufacturing sources; furnaces in Glass and Glass Product Manufacturing sources; and high-emitting equipment and large boilers in Basic Chemical Manufacturing, Petroleum and Coal Products Manufacturing sources and Pulp, Paper, and Paperboard Mills. This TSD also includes a discussion of municipal waste combustors, for which EPA is also considering whether emissions standards are necessary. This TSD provides additional information to supplement the discussion in the preamble to the proposed rule on the basis for EPA's proposed emissions limits for each non-EGU unit and industry. All non-EGU emission limits identified in the proposed rule are designed to achieve emission reductions through the installation of the control strategies identified in the *Screening Assessment of Potential Emissions Reductions, Air Quality Impacts, and Costs from Non-EGU Emissions Units for 2026* ("Non-EGU Screening Assessment memorandum"), which is available in the docket for this rulemaking. Finally, this TSD includes a discussion of the best information currently available to EPA on the feasibility of controls and related installation timing needs for these non-EGU industries.

2 Pipeline Transportation of Natural Gas

Based on available information in the National Emissions Inventory (NEI), EPA has determined that reciprocating engines are the largest collective sources of NOx emissions from the Natural Gas Transportation Industry in the states affected by this proposed FIP. As explained in the Non-EGU Screening Assessment memorandum, the largest potential NOX emission reductions are from natural gas-fired spark ignition engines. Based on the NEI data, EPA has not identified a potential for significant emission reductions from turbines and compression ignition engines in the states covered by the proposed FIP. The process descriptions, background on each engine type, and summaries of applicable "reasonably available control technology" (RACT) emission limits and permit conditions, as well as a discussion of available NOX controls, are summarized in an analysis developed by the Ozone Transport Commission entitled *Technical Information Oil and Gas Sector Significant Stationary Sources of NOX Emissions* (October 17, 2012) ("OTC Engine Study"). The three types of engines for which EPA is proposing emission limits in this proposed FIP are: 1) two stroke lean burn spark ignition engines, which are covered on pages 17-28 of the OTC Engine Study; four stroke lean burn spark ignition engines, which are covered on pages 30-42 of the OTC Engine Study; and four stroke rich burn spark ignition engines, which are covered on pages 44-52 of the OTC Engine Study.

EPA is proposing an applicability threshold for spark ignition engines of 1000 hp or more. Based on the Non-EGU Screening Assessment memorandum, engines with a potential to emit of 100 tpy or greater had the most significant potential for NOX emissions reductions. EPA reviewed available information in the NEI and determined that some engines above 1000 hp reported emissions above 100 tpy, while engines smaller than 1000 hp generally reported emissions below 100 tpy.[1] Specifically, EPA only noted two engines below 1000 hp that emitted more than 100 tpy, while over 200 engines over 1000 hp emitted greater than 100 tpy. In addition to the NEI data, EPA observed that uncontrolled emissions from engines can be as high as 16.8 grams per horsepower per hour (g/hp-hr).[2] In addition, operating hours can be as high as 7000 hours in a given year.[3] With these assumptions, EPA could justify regulating engines around 800 hp or more. Given the variability with operating hours and the available data indicating that average operating hours are below 7000 hours per year,[4] EPA is proposing to establish an applicability threshold of 1000 hp should capture the majority of potential emission reductions.

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[1] *See* 2017 NEI Engines Emissions.xlsx, available in the docket for this rulemaking.

[2] *U.S. Environmental Protection Agency*, Stationary Reciprocating Internal Combustion Engines: Technical Support Document for NOx SIP Call (October 2003); *U.S. Environmental Protection Agency*, Assessment of Non-EGU NOx Emission Controls, Cost of Controls, and Time for Compliance Final TSD, 5-8 (August 2016); *Illinois Environmental Protection Agency*, Technical Support Document for Controlling Emissions from Stationary Reciprocating Internal Combustion Engines and Turbines, 41 (March 19, 2007).

[3] *Illinois Environmental Protection Agency*, Technical Support Document for Controlling Emissions from Stationary Reciprocating Internal Combustion Engines and Turbines, 41 (March 19, 2007).

[4] OTC Engine Study, 88 (October 17, 2012) (explaining that the average operating hours was around 35% or around 3066 hours a year); *Illinois Environmental Protection Agency*, Technical Support Document for Controlling Emissions from Stationary Reciprocating Internal Combustion Engines and Turbines, 41 (March 19, 2007) (assuming operating hours for engines at 7000 hours a year); *U.S. Environmental Protection Agency*, Assessment of Non-EGU NOx Emission Controls, Cost of Controls, and Time for Compliance Final TSD, 5-6 through 5-9 (August 2016) (assuming operating hours of 2000 hours a year).

Federal Rules Affecting Engines

Natural gas-fired spark ignition engines are subject to the New Source Performance Standards (NSPS) for Stationary Spark Ignition Internal Combustion Engines (40 CFR part 60 subpart JJJJ) and National Emission Standards for Hazardous Air Pollutants (NESHAP) for Stationary Reciprocating Internal Combustion Engines (40 CFR part 63 subpart ZZZZ).

Four Stroke Lean Burn Spark Ignition Engines

For four stroke lean burn spark ignition engines, EPA is proposing an emissions limit of 1.5 g/hp-hr. EPA believes that installation of selective catalytic reduction (SCR) system or a combination of other controls technologies should be available for these engines to meet this emission limit. As explained in the OTC Engine Study, most of the four stroke lean burn spark ignition engines should be able to achieve 60 to 90% emission reductions with the installation of layered combustion controls, such as the installation of turbochargers and inter-cooling, pre-chamber ignition or high energy ignition, improved fuel injection control, air/fuel ratio control, etc.[5] Reduction in this range should be able to achieve an emissions limit of 1.5 g/hp-hr or less. For some engines that can only achieve a 60% reduction from layered combustion controls, information suggests that those engines should be able to install SCR to lower emissions to 1.5 g/hp-hr.[6]

Many states containing ozone nonattainment areas or located within the Ozone Transport Region (OTR) have already adopted emission limits similar to the proposed emissions limit of 1.5 g/hp-hr. While some states have required limits equivalent to or even lower than 0.5 g/hp-hr,[7] most states have adopted emission limits at or close to 1.5 g/hp-hr.[8] Additional examples of state RACT rules and permitted emission limits can be found in the "NO_X Permit Limits and RACT Tool spreadsheet" available in the docket. Many of these example RACT rules contain emission limits based on engine manufacture dates and set higher emissions limits between 1.5 and 3.0 g/hp-hr for older engines.

In addition to RACT limits, some four stroke lean burn spark ignition engines may have installed equipment to meet the emission limits contained within EPA's NSPS located at 40 CFR 60, Subpart JJJJ, which requires that these engines meet a NOx emissions limit of 1.0 g/hp-hr if manufactured on or after July 1, 2010 and a NOx emissions limit of 2.0 g/hp-hr if manufactured on or after July 1, 2007 but before July 1, 2010.[9] Given that many of the newer engines subject to this FIP are already required to meet the more stringent NSPS limits of 1.0 to 2.0 g/hp-hr, EPA's proposed FIP is targeting an emission limit that older engines not subject to the NSPS could still meet.

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[5] OTC Engine Study, 43.

[6] Id.

[7] See, e.g., South Coast Air Quality Management District Rule 1110.2, establishing a NO_X emissions limit of 36 ppmvd, which is equivalent to about 0.5 g/hp-hr.

[8] For example, see Colorado Air Quality Control Commission Regulation 7, Part E, Section I, Table 1 and Table 2 (establishing emissions limits at 0.7 to 2.0 g/hp-hr depending on engine construction dates).

[9] *See* 40 CFR part 60, Subpart JJJJ Table 1.

Based on the example RACT rules, applicability of the NSPS to newer engines, and the feasibility of NO_X reductions analyzed in the OTC Engine Study, EPA believes an emissions limit of 1.5 g/hp-hr is achievable by the vast majority of two stroke lean burn spark ignition engines and will achieve the necessary NO_X reductions for engines that are not subject to equivalent RACT requirements or the NSPS at 40 CFR 60, Subpart JJJJ.

Four Stroke Rich Burn Spark Ignition Engines

For four stroke rich burn spark ignition engines, EPA is proposing an emissions limit of 1.0 g/hp-hr. EPA believes that installation of non-selective catalytic reduction (NSCR) or a combination of other control technologies should be available for these engines to meet this emission limit. As explained in the OTC Engine Study, most of the four stroke rich burn spark ignition engines should be able to achieve 90 to 99% emission reductions with the installation of NSCR. OTC Engine Study at 45-46. A 90 to 99% emission reduction should result in an emissions level of 1.0 g/hp-hr or less.

Many states containing ozone nonattainment areas or located within the Ozone Transport Region (OTR) have already adopted emission limits similar to the proposed emissions limit of 1.0 g/hp-hr. While some states have required limits equivalent to or even lower than 0.2 g/hp-hr,[10] most states have adopted emission limits at or close to 1.0 g/hp-hr.[11] Additional examples of state RACT rules and permitted emission limits can be found in the "NO_X Permit Limits and RACT Tool spreadsheet" available in the docket. Many of these example RACT rules contain emission limits based on engine manufacture dates and set higher emissions limits at or close to 1.0 g/hp-hr for older engines.

In addition to RACT limits, some four stroke rich burn spark ignition engines may have installed equipment to meet the emission limits contained within EPA's NSPS located at 40 CFR 60, Subpart JJJJ, which requires that these engines meet a NOx emissions limit of 1.0 g/hp-hr if manufactured on or after July 1, 2010 and a NOx emissions limit of 2.0 g/hp-hr if manufactured on or after July 1, 2007 but before July 1, 2010. *See* 40 CFR part 60, Subpart JJJJ Table 1. Further, some of these same units will have already installed NSCR to comply with EPA's NESHAP for Stationary Reciprocating Internal Combustion Engines at 40 CFR Part 63 Subpart ZZZZ. Even though the NESHAP at subpart ZZZZ does not regulate NO_X emissions, the installation of NSCR on these units should already provide the co-benefit of reducing NO_X emissions to the levels necessary to comply with the proposed FIP. Given that many of the newer engines subject to this FIP are already required to meet the more stringent NSPS limits of 1.0 to 2.0 g/hp-hr, EPA's proposed FIP is targeting an emission limit that older engines not subject to the NSPS could still meet.

Based on the example RACT rules, applicability of the NSPS to newer engines, and the feasibility of NO_X reductions analyzed in the OTC Engine Study, EPA believes an emissions

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[10] See Pennsylvania General Permit 5 for Natural Gas Production and Processing Facilities, establishing NO_X emissions limits for four stroke rich burn engines as low as 0.2 g/hp-hr.

[11] For example, see Colorado Air Quality Control Commission Regulation 7, Part E, Section I, Table 1 and Table 2 (establishing emissions limits at 0.5 to 2.0 g/hp-hr depending on engine construction dates).

limit of 1.0 g/hp-hr is achievable by the vast majority of two stroke lean burn spark ignition engines and will achieve the necessary reductions.

Two Stroke Lean Burn Spark Ignition Engines

For two stroke lean burn spark ignition engines, EPA is proposing an emissions limit of 3.0 g/hp-hr. EPA believes that installation of layered combustion controls or a combination of other control technologies should be available for these engines to meet this emission limit. As explained in the OTC Engine Study, most of the two stroke lean burn spark ignition engines should be able to achieve 60 to 90% emission reductions with the installation of layered combustion controls, such as the installation of turbochargers and inter-cooling, pre-chamber ignition or high energy ignition, improved fuel injection control, and air/fuel ratio control. OTC Engine Study at 28. Available information suggests that some engines that can only achieve a 60% reduction from layered combustion controls will only be able to meet an emission limit of 3.0 g/hp-hr or greater. While some of these engines could install SCR to achieve greater reductions, EPA does not have information indicating that manufacturers and models of two stroke learn burn spark ignition engines generally can install the necessary combination of layered combustion controls and SCR. OTC Engine Study at 28.

Many states containing ozone nonattainment areas or located within the OTR have already adopted emission limits similar to the proposed emissions limit of 3.0 g/hp-hr. While some states have adopted limits equivalent to or even lower than 0.5 g/hp-hr,[12] most states have adopted emission limits between 1.0 g/hp-hr and 3.0 g/hp-hr.[13] Additional examples of state RACT rules and permitted emission limits can be found in the "NO_X Permit Limits and RACT Tool spreadsheet" available in the docket. Many of these example RACT rules contain emission limits based on engine manufacture dates and set higher emissions limits closer to 3.0 g/hp-hr for older engines.

In addition to RACT limits, some two stroke lean burn spark ignition engines may have installed equipment to comply with EPA's NSPS at 40 CFR part 60, subpart JJJJ, which requires that these engines meet a NOx emissions limit of 1.0 g/hp-hr if manufactured on or after July 1, 2010 and a NOx emissions limit of 2.0 g/hp-hr if manufactured on or after July 1, 2007 but before July 1, 2010. *See* 40 CFR part 60, Subpart JJJJ Table 1. Given that many of the newer engines subject to this proposed FIP are already required to meet the more stringent NSPS limits of 1.0 to 2.0 g/hp-hr, EPA's proposed FIP is targeting an emission limit that older engines not subject to the NSPS could still meet.

Based on the example RACT rules, applicability of the NSPS to newer engines, and the feasibility of NO_X reductions analyzed in the OTC Engine Study, EPA believes an emissions limit of 3.0 g/hp-hr is achievable by the vast majority of two stroke lean burn spark ignition engines and will achieve the necessary reductions for engines that are not subject to equivalent RACT requirements or the NSPS at 40 CFR part 60, subpart JJJJ.

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[12] See South Coast Air Quality Management District Rule 1110.2, establishing a NO_X emissions limit of 36 ppmvd or about 0.5 g/hp-hr.

[13] For example, see Colorado Air Quality Control Commission Regulation 7, Part E, Section I, Table 1 and Table 2 (establishing emissions limits at 1.0 to 3.0 g/hp-hr depending on engine construction dates).

3 Cement and Concrete Product Manufacturing

Process Description[14]

Portland cement is a fine powder, gray or white in color, that consists of a mixture of hydraulic cement materials comprising primarily calcium silicates, aluminates and alumino-ferrites. More than 30 raw materials are known to be used in the manufacture of portland cement, and these materials can be divided into four distinct categories: calcareous, siliceous, argillaceous, and ferrifrous (containing iron). These materials are chemically combined through pyroprocessing (heat) and subjected to subsequent mechanical processing operations to form gray and white portland cement. Gray portland cement is used for structural applications and is the more common type of cement produced. White portland cement has a lower iron and manganese content than gray portland cement and is used primarily for decorative purposes. The six-digit Source Classification Code (SCC) for portland cement plants with wet process kilns is 3-05-006, and the six-digit SCC for plants with dry process kilns is 3-05-007.

A diagram of cement production installation is shown below.[15]

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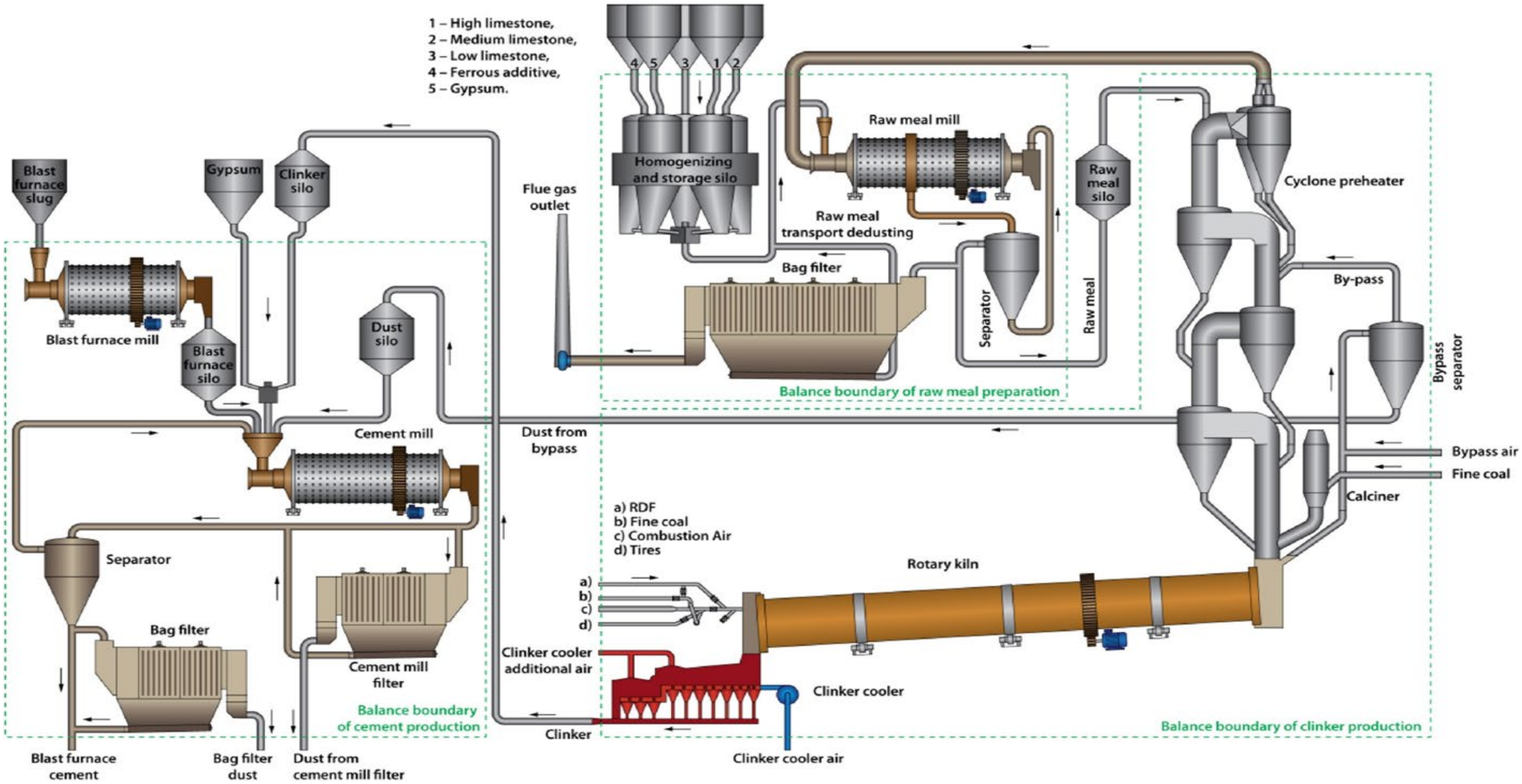
[14] See generally EPA, "AP-42 Compilation of Air Emissions Factors," Chapter 11, Mineral Products Industry, Section 11.6, Portland Cement Manufacturing, Final Section (January 1995).

[15] See Krzysztof Kogut, Jerzy Gorecki, and Piotr Burmistrz, "Opportunities for reducing mercury emissions in the cement industry," Journal of Cleaner Production, Volume 293, 126053, Figure 1: Diagram of cement production installation (April 15, 2021); available at https://www.sciencedirect.com/science/article/pii/S0959652621002730 (URL dated 8 November 2021).

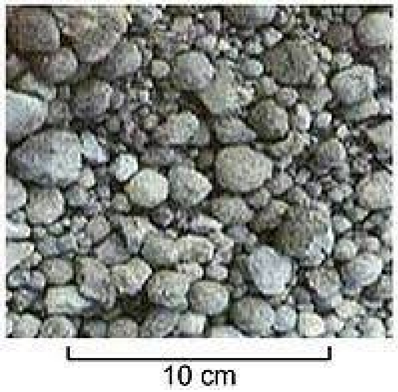


Reproduced from Krzysztof Kogut, Jerzy Gorecki, and Piotr Burmistrz, "Opportunities for reducing mercury emissions in the cement industry," Journal of Cleaner Production, Volume 293, 126053, Figure 1: Diagram of cement production installation (April 15, 2021); available at https://www.sciencedirect.com/science/article/pii/S0959652621002730 (URL dated 8 November 2021).

Cement Kilns[16]

Cement kilns are used by the cement industry in the production of cement. Portland cement, used in almost all construction applications, is the industry's primary product. Essentially all of the Oxides of Nitrogen (NOx) emissions associated with cement manufacturing are generated in the kilns because of high process temperatures.

To manufacture cement, raw materials such as limestone, cement rock, sand, iron ore, clay and shale are crushed, blended, and fed into a kiln. These materials are then heated in the kiln to temperatures above 2900°F to induce a chemical reaction (called "fusion") that produces cement "clinker," a round, marble-sized, glass-hard material. The clinker is then cooled, mixed with gypsum and ground to produce cement. Clinker is also defined as the product of a portland cement kiln from which finished cement is manufactured by milling and grinding. See the picture below.



Nearly all cement clinker is produced in large rotary kiln systems. The rotary kiln is a refractory brick-lined cylindrical steel shell equipped with an electrical drive to rotate it at 1-3 revolutions per minute, through which hot combustion gases flow counter-currently to the feed materials. The kiln can be fired with coal, oil, natural gas, waste (solvents) or a combination of these fuels.

Various types of kilns are in use: long wet kilns, long dry kilns, kilns with a preheater and kilns with a precalciner. The long wet and dry kilns and most preheater kilns have only one fuel combustion zone, whereas the newer precalciner kilns and preheater kilns with a riser duct have two fuel combustion zones.

In a wet kiln, the ground raw materials are suspended in water to form a slurry and introduced into the inlet feed. This kiln type employs no preheating of the dry feed.

The basic principle of a wet-process kiln is shown below.

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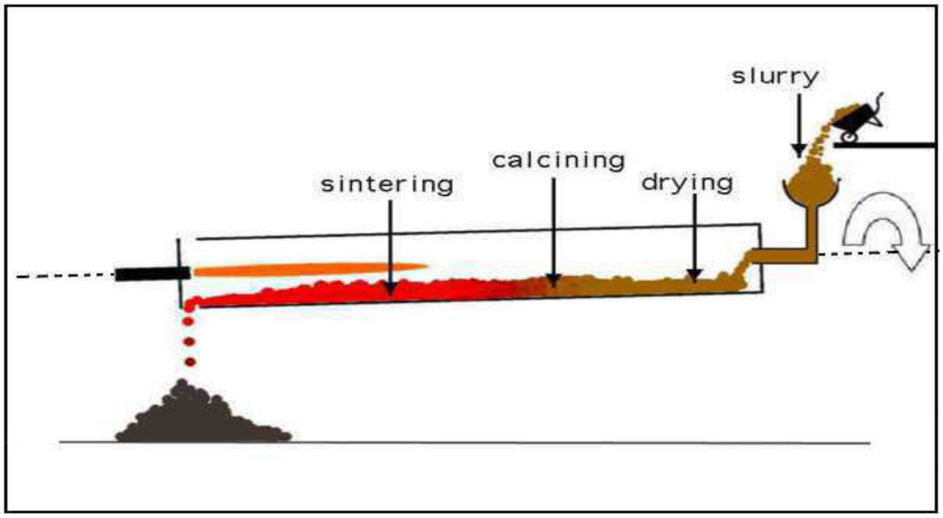
[16] See generally STAPPA/ALAPCO, Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options, 72-73 (July 1994).

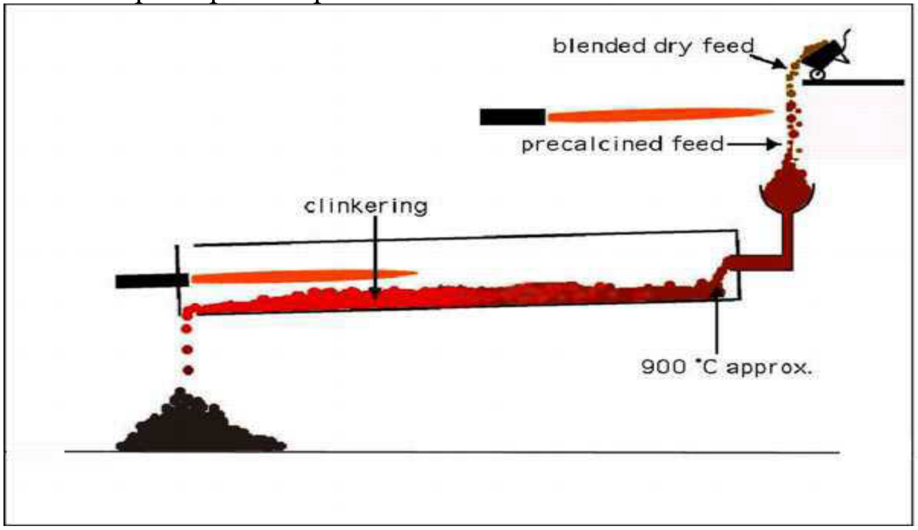


Reproduced from Nicholas B. Winter, Understanding Cement, WHD Microanalysis Consultants Ltd. (December 2012), available at https://www.understanding-cement.com/kiln.html (URL dated 20 October 2021).

In a long dry kiln, the raw materials are dried to a powder and introduced into the inlet feed in a dry form, but this kiln type employs no preheating of the dry feed. Currently more cement plants use the dry process because of its lower energy requirement.

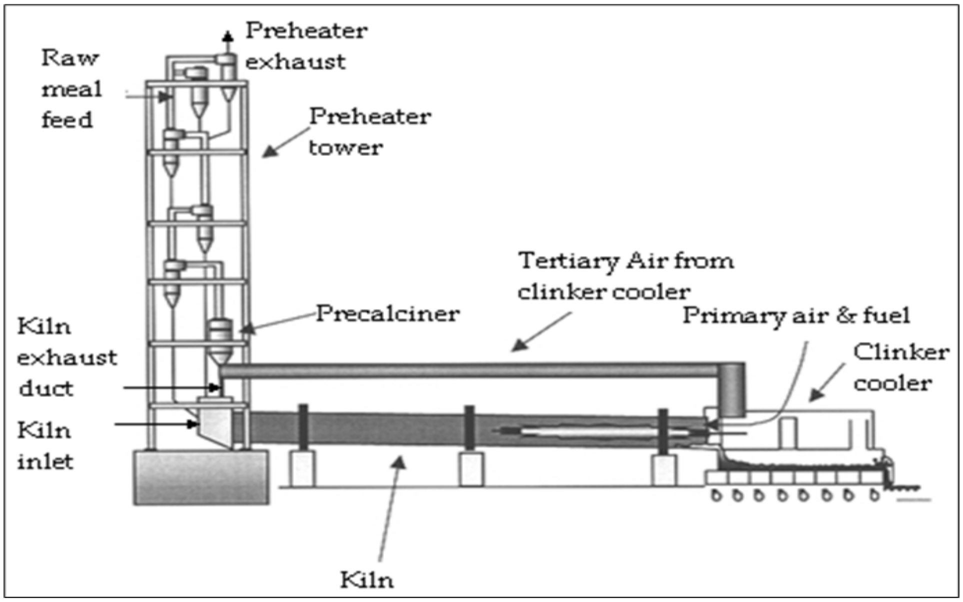
In a precalciner kiln, the feed to the kiln system is preheated in cyclone chambers and utilizes a second burner to calcine material in a separate vessel attached to the preheater before the final fusion in a kiln that forms clinker.

The basic principle of a precalciner cement kiln is shown below.



Reproduced from Nicholas B. Winter, Understanding Cement, WHD Microanalysis Consultants Ltd. (December 2012), available at https://www.understanding-cement.com/kiln.html (URL dated 20 October 2021).

A kiln where the feed to the kiln system is preheated in cyclone chambers before the final fusion in a kiln that forms clinker is referred to as preheater kiln.



Reproduced from Ozone Transport Commission, White Paper on Control Measures for Nitrogen Oxides (NOx) Emissions from Two Source Categories, 15 (August 28, 2017).

The majority of newer cement plants use the preheater and precalciner system. The basic principle of a precalciner cement kiln is shown above.

Because the typical operating temperatures of these kilns differ, the NOx formation mechanisms also differ among these kiln types. In a primary combustion zone at the hot end of a kiln, the high temperatures lead to predominantly thermal NOx formation. In the secondary combustion zone, however, lower gas-phase temperatures suppress thermal NOx formation. Energy efficiency is also important in reducing NOx emissions. For example, a high thermal efficiency equates to less heat and fuel consumed and, therefore, less NOx is produced.

Federal Rules Affecting Cement Plants

Cement plants are subject to the Portland Cement NESHAP (40 CFR part 63 subpart LLL) and NSPS (40 CFR part 60 subpart F). Cement kilns that burn hazardous waste are subject to the Hazardous Waste Combustor NESHAP (40 CFR part 63 subpart LLL). Cement kilns that burn non-hazardous solid wastes are subject to the Commercial and Industrial Solid Waste Incinerator Units (CISWI) rule (40 CFR part 60 subparts CCCC and DDDD).

Technology-Based Federal Regulations

The NSPS implementing Clean Air Act (CAA) section 111(b) for Portland Cement Plants was first promulgated at 40 CFR part 60, subpart F on December 23, 1971 (36 FR 24876). EPA conducted three additional reviews of these standards on June 14, 1974 (39 FR 20793), November 12, 1974 (39 FR 39874) and December 14, 1988 (53 FR 50354). NOx emissions were not regulated under part 60, subpart F at that time.

On June 16, 2008 (73 FR 34072), EPA proposed amendments to the NSPS for Portland Cement Plants. The proposed amendments included revisions to the emission limits for affected facilities which commence construction, modification, or reconstruction after June 16, 2008. Among other things, EPA proposed establishing a NOx emission limit for cement kilns at portland cement plants.[17]

On September 9, 2010 (75 FR 54970) EPA finalized the proposed amendments to the NSPS establishing a NOx emission limit, among other things, for portland cement plants that commence construction, modification, or reconstruction after June 16, 2008. This final rule became effective on November 8, 2010 and is codified at 40 CFR part 60 subpart F.

NOx Controls

The National Association of Clean Air Agencies (NACAA, formerly STAPPA/ALAPCO) has recommended requiring combustion controls and Selective Non-Catalytic Reduction (SNCR) to achieve NOx reductions of up to 70 percent on certain processes at cement kilns.[18] SNCR is a post combustion control technology used to reduce NOx emissions without the presence of a catalyst. Reagent (Ammonia or Urea) is injected directly into flue gas and reacts with NOx resulting in Nitrogen (N_2) and water (H_2O).

SNCR avoids the problems related to catalyst fouling (poisoning) that occur during use of Selective Catalytic Reduction (SCR) technology, but requires injection of the reagents in the kiln at a temperature between 1600 to 2000°F, which is much higher than the typical temperatures for SCR operation (550-800°F). At these temperatures urea decomposes to produce ammonia which is responsible for NOx reduction. Because of the temperature constraint, SNCR technology is only applicable to preheater and precalciner kilns.[19] Preheater and precalciner kilns require relatively simple SNCR installations. In preheater/precalciner kiln design, the SNCR injection ports can be installed in the combustion zone in the calciner, the oxidation zone of the upper air inlet before the deflection chamber, or in the area after the mixing chamber before the inlet to the bottom. SNCR has been installed and is currently operating on numerous kilns in Europe and the U.S.

SCR is a process that uses ammonia in the presence of a catalyst to selectively reduce NOx emissions from exhaust gases. This technology, at first, was widely used for NOx abatement in other industries, such as coal-fired power stations and waste incinerators. In SCR, anhydrous ammonia, usually diluted with air or steam, is injected through a grid system into hot flue gases which are then passed through a catalyst bed to carry out NOx reduction reactions. Ammonia is typically injected to produce a NH_3:NOx molar ratio of 1.05-1.1:1 to achieve a NOx conversion of 80 to 90 percent with an ammonia "slip" of about 10 ppm of unreacted ammonia in the gases leaving the reactor. In the cement industry, basically two SCR systems are being considered: low dust exhaust gas and high dust exhaust gas treatment. Low dust exhaust gas systems require reheating of the exhaust gases after dedusting, resulting in additional cost. High

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[17] 73 FR 34072 (proposed NSPS for Portland Cement Plants), Docket IN No. EPA–HQ–OAR–2007–0877.

[18] STAPPA/ALAPCO, Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options, 72-73 (July 1994).

[19] EPA, NOx Control Technologies for the Cement Industry: Final Report, 6 (September 2000).

dust systems are considered preferable for technical and economical reasons.[20] While SCR installations are not common at cement kilns in the U.S, EPA is aware of one SCR system that has been installed on a cement kiln in Joppa, Illinois.[21]

The European Union Commission charged with establishing the Best Available Techniques (BAT) to control NOx emissions from the production of cement outlines the following control techniques tabulated below.

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[20] Official Journal of European Union Commission, Best Available Techniques (BAT) Conclusions Under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for the Production of Cement, Lime and Magnesium Oxide, March 26, 2013, at 42.

[21] State of Illinois Clean Air Act Program Permit No. 95090119 (issued September 11, 2018, to Holcim US, Inc. - Joppa Plant, 2500 Portland Road, Grand Chain, IL 62941), Section 4.1 Cement Kilns and Clinker Coolers, Kiln #1. See also Lafarge, North America, Inc., Clean Air Act Settlement (overview of injunctive relief, available at https://www.epa.gov/enforcement/lafarge-north-america-inc-clean-air-act-settlement (URL dated October 12, 2021)).

Primary Techniques/Measures	**Description**
Flame Cooling	The addition of water to the fuel or directly to the flame by using different injection methods, such as injection of one fluid (liquid) or two fluids (liquid and compressed air or solids) or the use of liquid/solid wastes with a high water content reduces the temperature and increases the concentration of hydroxyl radicals. This can have a positive effect on NOx reduction in the burning zone.
Low NOx Burners	Designs of low NOx burners (indirect firing) vary in detail but essentially the fuel and air are injected into the kiln through concentric tubes. The primary air proportion is reduced to some 6 - 10% of that required for stoichiometric combustion (typically 10 - 15% in traditional burners). Axial air is injected at high momentum in the outer channel. The coal may be blown through the center pipe or the middle channel. A third channel is used for swirl air, its swirl being induced by vanes at, or behind, the outlet of the firing pipe. The net effect of this burner design is to produce very early ignition, especially of the volatile compounds in the fuel, in an oxygen-deficient atmosphere, and this will tend to reduce the formation of NOx. The application of low NOx burners is not always followed by a reduction of NOx emissions. The set-up of the burner has to be optimized.
Mid Kiln Firing	In long wet and long dry kilns, the creation of a reducing zone by firing lump fuel can reduce NOx emissions. As long kilns usually have no access to a temperature zone of about 900 -1000°C, mid-kiln firing systems can be installed in order to be able to use waste fuels that cannot pass the main burner (for example tires). The rate of the burning of fuels can be critical. If it is too slow, reducing conditions can occur in the burning zone, which may severely affect product quality. If it is too high, the kiln chain section can be overheated - resulting in the chains being burned out. A temperature range of less than 1100°C excludes the use of hazardous waste with a chlorine content of greater than 1%.
Addition of mineralizers to improve the burnability of the raw meal (mineralized clinker)	The addition of mineralizers, such as fluorine, to the raw material is a technique to adjust the clinker quality and allow the sintering zone temperature to be reduced. By reducing/lowering the burning temperature, NOx formation is also reduced.
Staged combustion (conventional or waste fuels), also in combination	Staged combustion is applied at cement kilns with an especially designed precalciner. The first combustion stage takes place in the rotary kiln under optimum conditions for the clinker burning process. The second combustion stage is a burner at the kiln inlet, which produces a reducing

Primary Techniques/Measures	**Description**
with a precalciner and the use of optimized fuel mix	atmosphere that decomposes a portion of the nitrogen oxides generated in the sintering zone. The high temperature in this zone is particularly favorable for the reaction which reconverts the NOx to elementary nitrogen. In the third combustion stage, the calcining fuel is fed into the calciner with an amount of tertiary air, producing a reducing atmosphere there, too. This system reduces the generation of NOx from the fuel, and also decreases the NOx coming out of the kiln. In the fourth and final combustion stage, the remaining tertiary air is fed into the system as 'top air' for residual combustion.
SNCR	Selective non-catalytic reduction (SNCR) involves injecting ammonia water (up to 25% NH_3), ammonia precursor compounds or urea solution into the combustion gas to reduce NO to N_2. The reaction has an optimum effect in a temperature window of about 830 - 1050°C, and sufficient retention time must be provided for the injected agents to react with NO.
SCR	SCR reduces NO and NO_2 to Nitrogen with the help of NH_3 and a catalyst at a temperature range of 300 - 400°C. This technique was initially started for NOx abatement in other industries (coal fired power stations, waste incinerators) and is now available in the cement manufacturing industry.

Reproduced from Official Journal of European Union Commission, Best Available Techniques (BAT) Conclusions Under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for the Production of Cement, Lime and Magnesium Oxide, March 26, 2013, Table 1.5.2.

EPA's Menu of Control Measures (MCM) provides state, local and tribal air agencies with information on existing criteria pollutant emission reduction measures as well as relevant information concerning the efficiency and cost effectiveness of the measures.[22] State, local, and tribal agencies may use this information in developing emission reduction strategies, plans and programs to assure they attain and maintain the NAAQS. The information from the MCM can also be found in the Control Measures Database (CMDB), a major input to the Control Strategy Tool (CoST), which EPA used in the NOx control strategy analysis included in the Non-EGU Screening Assessment memorandum.[23] Information about control measures to reduce NOx emissions from cement kiln operations is tabulated below.

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[22] EPA, Menu of Control Measures for NAAQS Implementation, available at https://www.epa.gov/air-quality-implementation-plans/menu-control-measures-naaqs-implementation (URL dated January 5, 2022).

[23] EPA, Control Measures Database (CMDB) for Stationary Sources, available at https://www.epa.gov/system/files/other-files/2021-09/cmdb_2021-09-02_0.zip (URL dated January 6, 2022).

Source Category	**Emission Reduction Measure**	**Control Efficiency (%)**	**Description/Notes/Caveats**	**References**
Cement kilns	Biosolid Injection Technology	23	This control is the use of biosolid injection to reduce NOx emissions. This control applies to cement kilns.	EPA 2006b, EPA 2007c
Cement kilns	Changing feed composition	25-40	This control is changing the cement formulation by adding steel slag to lower the clinkering temperatures and suppress NOx. The patented feed modification technique known as the CemStar Process is a raw feed modification process that can reduce NOx emissions by about 30 percent and increase production by approximately 15 percent. It involves the addition of a small amount of steel slag to the raw kiln feed. Steel slag has a chemical composition similar to clinker and many of the chemical reactions required to convert steel slag to clinker take place in the steel furnace. By substituting steel slag for a portion of the raw materials, facilities can increase thermal efficiency and thereby reduce NOx emissions. This control is applicable to wet- and dry-process kilns, as well as those with preheaters or precalciners.	STAPPA/ALAPCO 2006
Cement Kilns	Process Control Systems	<25	This control is the modification of the cement production process to improve fuel efficiency, increase capacity and kiln operational stability. NOx reductions result from the increase in productivity and reduced energy use. One process control that specifically targets NOx emissions is continuous emissions monitoring systems (CEMS). CEMS allow operators to continuously monitor oxygen and carbon monoxide (CO) emissions in cement kiln exhaust gases. The levels of these gases indicate the amount of	STAPPA/ALAPCO 2006

Source Category	**Emission Reduction Measure**	**Control Efficiency (%)**	**Description/Notes/Caveats**	**References**
			excess air in the combustion zone. At a given excess air level, NOx emissions increase as the temperature increases. Knowing the excess air level allows operators to maintain a lower temperature and thereby minimize NOx creation. Studies indicate that reducing excess air by half can reduce NOx emissions by about 15 percent. This control is applicable to wet- and dry-process kilns, as well as those with preheaters or precalciners.	
Cement Manufacturing - Dry Process	Selective Non-Catalytic Reduction - Ammonia	50	This control is the reduction of NOx emission through ammonia based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). This control applies to dry-process cement manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994h
Cement Manufacturing - Dry Process	Selective Non-Catalytic Reduction – Urea	50	This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). This control applies to dry-process cement manufacturing with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h
Cement Manufacturing - Dry Process or Wet Process	Low NOx Burner	25	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h, EC/R 2000

Source Category	Emission Reduction Measure	Control Efficiency (%)	Description/Notes/Caveats	References
			one combustion zone and reducing the amount of oxygen available in another. This control applies to dry-process or wet-process cement manufacturing operations with indirect-fired kilns with uncontrolled NOx emissions greater than 10 tons per year.	
Cement Manufacturing - Dry Process or Wet Process	Mid-Kiln Firing	30	This control is the use of mid-kiln firing to reduce NOx emissions. Mid-kiln firing is the injection of solid fuel into the calcining zone of a long kiln. This allows for part of the fuel to be burned at a lower temperature, reducing NOx formation. This control applies to wet-process and dry-process cement manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994h, EC/R 2000
Cement Manufacturing - Wet Process	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to wet-process cement manufacturing with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b

Reproduced from EPA, Menu of Control Measures for NAAQS Implementation, available at https://www.epa.gov/air-quality-implementation-plans/menu-control-measures-naaqs-implementation (URL dated January 5, 2022).

The table below presents NOx control techniques and the types of kilns on which they may be applied.[24]

NOx Control Technique	**Applicable Kiln Type**			
	Long Wet	Long Dry	Preheater	Precalciner
Process Control Systems	Yes	Yes	yes	yes
CemStar	Yes	Yes	yes	yes
Low-NOx Burner [a]	Yes	Yes	yes	yes
Mid-Kiln Firing	Yes	Yes	no	no
Tire Derived Fuel [b]	Yes	Yes	yes	yes
SNCR	No	No	yes	yes

[a] Low-NOx burners can only be used on kilns that have indirect firing.

[b] Tire derived fuel can be introduced mid-kiln in a wet or long-dry kiln, or at the feed end of a preheater or precalciner kiln.

Reproduced from EPA, "NOx Control Technologies for the Cement Industry, Final Report," EPA-457/R-00-002 (September 2000), at 76.

State RACT Rules

EPA reviewed information provided in a SIP submission from the Texas Commission on Environmental Quality (TCEQ) concerning NOx control technologies that have been implemented at portland cement plants.[25]

Texas, Ellis County -Three companies currently operate four kilns in Midlothian, Ellis County. Since 2015, no cement plant is using wet kilns.

Ash Grove Cement Company (Ash Grove) operated three kilns in Ellis County. However, a 2013 consent decree with EPA required by September 10, 2014 shutdown of two kilns and reconstruction of kiln #3 with SNCR with an emission limit of 1.5 pounds of NOx per ton of clinker and a 12-month rolling tonnage limit for NOx of 975 tpy. The reconstructed kiln is a dry kiln with year-round SNCR operation and is subject to the 1.5 lb NOx/ton of clinker emission standards in the NSPS for Portland Cement Plants. The TCEQ has the delegated authority to enforce this standard through the agency's general NSPS delegation and the NSPS satisfies RACT for Ash Grove.[26]

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[24] EPA, "NOx Control Technologies for the Cement Industry, Final Report," EPA-457/R-00-002 (September 2000), at 76.

[25] See TCEQ, Appendix F, Reasonably Available Control Technology Analysis, Dallas-Fort Worth Serious Classification Attainment Demonstration SIP Revision, TCEQ Project Number 2019-078-SIP-NR, available at https://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/dfw_ad_sip_2019/DFWAD_19078SIP_Appendix_F_pro.pdf (URL dated October 12, 2021).

[26]Delegation Documents for State of Texas, see https://www.epa.gov/tx/region-6-delegation-documents-state-texas-0

Holcim U.S., Inc. (formerly Holnam) currently has two dry preheater/precalciner (PH/PC) kilns equipped with SNCR. On January 14, 2009, EPA approved the current source cap of 5.3 tons per day (tpd) NOx for Holcim at 30 TAC §117.3123 as satisfying RACT for 1997 8-hours ozone NAAQS.[27]

Texas Industries, Inc. (TXI) currently operates one dry (PH/PC) kiln #5. The permitted capacity of this kiln is 2,800,000 tons of clinker per year, and it has a permitted emissions factor of 1.95 lb NOx/ton of clinker. Based on these permit limits, this kiln is therefore limited to a maximum of 7.48 tpd NOx, compared to the current 30 TAC §117.3123 source cap of 7.9 tpd NOx. Kiln #5 typically operates well below the source cap, at an average emission factor below 1.5 lb NOx/ton of clinker. EPA approved this limit as RACT on February 22, 2019 (84 FR 5601). The current NOx Source Cap (tpd) for Ellis County cement plants is shown below.

Cement Plant	**NOx Cap - tpd**
Ash Grove	4.4
Holcim	5.3
TXI	7.9
Total	17.6

Emission Limits and Compliance Requirements in the Proposed Rule.

In setting the emission limits for Long Wet kilns, EPA considered a range of emission limits from 3.88 to 6.0 lb/ton of clinker produced. In particular, EPA notes that it has approved a Texas rule requiring 4.0 lb/ton of clinker. *See* 74 FR 1927 (January 14, 2009) (approving Texas Administrative Code (TAC), title 30, chapter 117, section 117.3110(a)(1)(B), among other provisions).

For Preheaters, EPA based the emission limit of 3.8 on EPA-approved Texas and Illinois standards. *See, e.g.*, Appendix F, Reasonably Available Control Technology Analysis, https://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/dfw_ad_sip_2019/DFWAD_19078SIP_Appendix_F_pro.pdf (URL dated October 12, 2021); Illinois 35 IAC 217.224(a).

For Preheater/Precalciners, EPA based the emission limit of 2.8 lb/ton on Maryland and Illinois's approved standards and example permit limits. *See* MDAQMD Rule 1161 (C)(2); Mitsubishi Cement Corporation Lucerne Valley Federal Operating Permit 11800001; Illinois 35 IAC 217.224(a); January 14, 2009 (74 FR 1927), Docket ID No. EPA-R06-OAR-2007-1147; and January 14, 2009 (74 FR 1903), Docket ID No. EPA-R06-OAR-2007-0524 both dockets available at www.regulations.gov, also 30 TAC 117.3110(a)(4).

Performance Test and Monitoring

Notwithstanding any other provisions of the Act, EPA is proposing to require that performance tests be conducted on semiannual basis and conducted in accordance with the requirements of 40 CFR 60.8.

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[27] January 14, 2009 (74 FR 1927).

EPA is specifically soliciting comment on whether it is feasible or appropriate to require affected units (kilns) to be equipped with continuous emission monitoring systems (CEMS) to measure and monitor the NOx concentration (emissions level) instead of conducting performance tests on semiannual basis.

We are also soliciting comment on whether it is appropriate for the affected units (kilns) to use continuous parametric monitoring systems (CPMS[28]) instead of CEMS to monitor the NOx concentration (emissions level). We note that CPMS, also called parametric monitoring, measures a parameter (or multiple parameters) that is a key indicator of system performance. The parameter is generally an operational parameter of the process or the air pollution control device (APCD) that is known to affect the emissions levels from the process or the control efficiency of the APCD. Examples of parametric monitoring include kiln feed rate, clinker production rate, fuel type, fuel flow rate, specific heat consumption, secondary air temperature, kiln feed-end temperature, preheater exhaust gas temperature, induced draught fan pressure drop, kiln feed-end percentage oxygen, percentage downcomer oxygen, primary air flow rate, ammonia feed rate and slippage.

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[28] Basic Information about Air Emissions Monitoring, https://www.epa.gov/air-emissions-monitoring-knowledge-base/basic-information-about-air-emissions-monitoring (URL dated November 10, 2021).

4 Iron and Steel Mills and Ferroalloy Manufacturing+

Process Description

The steel and iron making processes are iterative processes during which iron is first produced and then further refined to steel. The most common furnace types used for iron and steel production are blast furnaces, basic oxygen process furnaces (BOF), electric arc furnaces (EAF), annealing furnaces and ladle metallurgy furnaces (LMF).

NOx emissions from iron and steel production are most often thermal NOx from the combustion of fossil fuels and other raw materials in furnaces or ancillary processes. The mixture of air and fuel in the furnace react to form NOx. Fuel and prompt NOx are also generated through oxidation of nitrogen compounds within the fossil fuels and the oxidation of hydrogen cyanide (HCN), respectively.

Iron

The raw materials used for iron production can include iron ore, coke, sinter, and stone. Production of coke involves carbonization of coal at high temperatures to concentrate the carbon. Commercial coke is generally made in one of two ways: (1) by-product coking and (2) non-recovery/heat recovery coking. A majority of the coke produced in the United States comes from by-product coking, where the coal is carbonized in large ovens and the resulting gas is collected and processed to recover various carbon-based by-products, such as naphthalene, benzene, toluene and xylene. In facilities using the non-recovery coking process, the ovens are heated differently from recovery coking operations such that no external heat source is required and instead of recovering chemical byproducts, heat is recovered and can be used to produce steam and electricity. The high temperatures required in coke ovens for carbonization allows the coal to soften, liquify, and re-solidify into a solid and porous material called "coke." The process of the coal entering the coke oven (or raw material in a blast furnace as discussed below) is called “charging,” and once the process is complete, the coke is “pushed” from furnaces, typically into a quenching car. Often situated in front of a bank of coke ovens, a separate machine is responsible for opening the coke oven doors, charging and pushing the raw material, and closing the oven again. This machine is often termed a larry car, or charging and pushing machine, among other terms. The car containing the pulverized coal then discharges the coal into the coke oven and the head of the pusher utilizes roller supports to push finished coke into the car, then the car transports the coke to a quench tower for water-based quenching. After a period of cooling, this newly produced coke is mixed with the other raw materials as it is charged into the blast furnace. Taconite is a hard, banded rock containing low-grade iron ore used to make iron and steel, mined in the Mesabi Iron Range in Northern Minnesota, and is the predominant iron ore in the United States. Processing taconite begins with crushing and grinding the ore and using magnetic separation or flotation to extract the iron. Typically, 33 percent of the taconite ore results in usable product for iron production.[29] The taconite ore is further processed through pelletization, creating either acid or flux pellets by combining the ore with a binder, typically

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[29] *See generally* EPA, AP 42 Compilation of Air Pollutant Emission Factors, Chapter 11, Mineral Products Industry, Section 11.23, Taconite Ore Processing, Final Section – Supplement C (February 1997), available at *https://www3.epa.gov/ttnchie1/old/ap42/ch11/s23/final/c11s23_feb1997.pdf*

moistened bentonite clay or limestone, in a balling drum and consequently fired at high temperatures to harden, a process referred to as induration. Types of indurating furnaces include the vertical shaft furnace, straight grate and grate/kiln furnaces, the latter being the most common. NO_X emissions are generated in gas waste streams from induration furnaces, in higher concentrations when producing flux pellets due to higher temperature requirements.

Production of sinter recovers the raw material value of many waste materials generated at iron and steel plants that would otherwise be landfilled or stockpiled.[30] Sinter, a hard-fused material, can be a compilation of ore fines, coke, blast furnace dust, mill scale, recycled hot and cold fines from the sintering process, limestone, calcite fines, and other supplemental materials to meet the correct specifications for use in a blast furnace for iron production.

A blast furnace is a counter-flow pressurized reactor. The raw material, referred to as "burden," is entered at the top of the furnace, and the gases (primarily N_2, CO, and CO_2) driving the reactions within the furnace, move upward. Blast furnace gas is ideally recirculated within the vessel. The shape and structure of the burden allows the hot gases to permeate the raw material as it moves upward through the furnace. Incoming air is preheated in a series of stoves, which is then blasted into the furnace. As the raw material and gases react, a layer of molten iron forms at the bottom of the furnace, and the top contains a layer of molten slag, which contains the impurities within the raw materials. Because it is less dense, it floats at the top of the blast furnace. A skimmer gathers the slag as it leaves the blast furnace and carries to a slag pit, while the molten iron is carried through troughs to a torpedo car, or refractory-lined rail car. The torpedo car is then transferred to the BOF for steel production.

Steel

Prior to steel refining, desulfurization of the molten iron must occur, typically in a BOF Shop by adding carbide-lime or lime-magnesium to the hot metal to create a reaction to remove sulfur. A BOF is described as basic due to the refractory lining of the furnace made from dolomite and magnesite, or "basic," alkaline materials that won't be altered by high temperatures, corrosion or abrasion during charging and blowing. In the BOF vessel, metal scrap is charged first, followed by molten iron from the blast furnace. Oxygen is blown into the BOF vessel, oxidizing the carbon within the steel. This creates CO and CO_2, and the vessel is rotated. The resulting refined steel can be tapped out at the bottom of the rotated vessel to avoid needing to skim slag from the top of the molten steel. Ambient air emissions are generated at the charging, melting, refining, and slag handling stages of the BOF steelmaking and refining operations, and the highest emissions come from the oxygen blowing stage.[31] These resultant gases are treated through semi-wet, wet-open or wet-suppressed combustion practices in a large main collection stack. These control methods regulate temperature and humidity for ESP or baghouse emission controls, draw excess air into the exhaust system to combust carbon dioxide prior to scrubbing

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[30] *See* EPA, Office of Air Quality Planning and Standards, Available and Emerging Technologies for Reducing Greenhouse Gas Emissions from the Iron and Steel Industry (September 2012), available at https://www.epa.gov/sites/default/files/2016-11/documents/iron-steel-ghg-bact-2012.pdf.

[31] *See* ITP Steel, Energy Use in the U.S. Steel Industry: An Historical Perspective and Future Opportunities (September 2000), available at https://www.energy.gov/eere/amo/downloads/itp-steel-energy-use-us-steel-industry-historical-perspective-and-future.

for particulate control, or conversely, exclude excess air for combustion of CO after scrubbing, respectively. Other emission sources from the BOF Shop, like charging and tapping, typically have control measures before entering the primary exhaust collection, such as charging hoods.

EAFs are utilized to melt scrap steel using radiant heat from an electric arc formed between electrodes placed inside the vessel during melting. While usage of electricity for steel melting allows some NOx generated to be transferred to a utility generating plant, oxygen and natural gas are often used to preheat the ladles that transfer hot metal to the EAF, causing an additional source of NOx emission. Ladle metallurgy, also known as secondary steelmaking, is the process of refining the metal chemistry of the molten steel produced by addition of ferroalloys to reach the steel product specifications. LMFs can refine steel more efficiently by transferring the steel from BOFs or EAFs to a ladle and adding aluminum and other alloys for more precise deoxidation. A vacuum degassing system added over the ladle allows further refinement of the molten steel, forcing the steel into the degassing system by inserting argon gas. Oxygen or nitrogen in the degassing system removes carbon from the steel by way of carbon monoxide or carbon dioxide formation. Other gases are used for removal of hydrogen. After steel is fully refined to the desired specifications, the molten steel is transferred to a tundish, or ladle, before casting. A tundish or ladle is a refractory-lined vessel for even distribution, temperature, and composition of steel. To minimize heat loss and damage to the refractory from the molten steel, the tundish and the ladle are preheated to high temperatures to be comparable to that of the molten metal. While the process generates NOx emissions through combustion, preheating a ladle or tundish is a crucial step in decreasing energy consumption of the process, as heating a cold ladle has been demonstrated to achieve less than 10% efficiency and variable metal quality.[32] Similarly, annealing and galvanizing steel processes and associated annealing and reheat furnaces involve reheating steel products with gas fired burners and are also a source of NOx emissions. Annealing involves a supplemental heating process to change the hardness properties of the final steel produced and ensure homogeneity. The galvanizing process coats iron or steal in a coating of molten zinc to protect and seal, limiting rust and corrosion. Reheat furnaces are used in hot rolling mills to heat steel slabs for rolling into sheets and represent 67% of the energy used in a steel industry.[33]

Ferroalloys

Like iron and steel, ferroalloys are produced in a variety of furnace types, including EAFs and LMFs. Ferroalloy refers to a chemical compound in which an alloy incorporates reactive elements, in many cases into iron and steel, to create distinctive qualities in a metal product. Mainly chromium, manganese, and silicon are introduced in the iron and steel making process, but ferroalloys can also commonly include boron, cobalt, columbium, copper, nickel, molybdenum, phosphorus, titanium, tungsten, vanadium, and zirconium. For example, incorporation of chromium increases corrosive resistance in stainless steels, silicon is added to

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[32] *See* Alsoufi, Mohammad & Yunus, Mohammed & Asadulla, Mohammed, Economical and Technical Way of Ladle Pre-heating by the Use of Flameless Oxyfuel (HSD/LPG) Gas in the Steel Industry, Elixir International Journal, 95, 40776-40781 (2016).

[33] Mariños Rosado, Diego & R.Ch, Samir R. & Gutierrez, Jordan & Huaraz, Miguel & Carvalho, Joao & Mendiburu, Andrés. Reheating Furnaces in the Steel Industry: Determination of the Thermal Powers in the Combustion of Coke Oven Gas, Linz-Donawitz Gas and Blast Furnace Gas, 10.26678/ABCM.ENCIT2020.CIT20-0016 (2020).

help remove oxygen in steel production and manganese helps to counteract unwanted effects of sulfur in iron and steel production, such as brittleness of steel and lessened corrosion resistance. Like iron and steel, ferroalloys are produced in a variety of furnace types, including EAFs and LMFs.

Several diagrams of the iron, steel and ferroalloy processes are shown below.

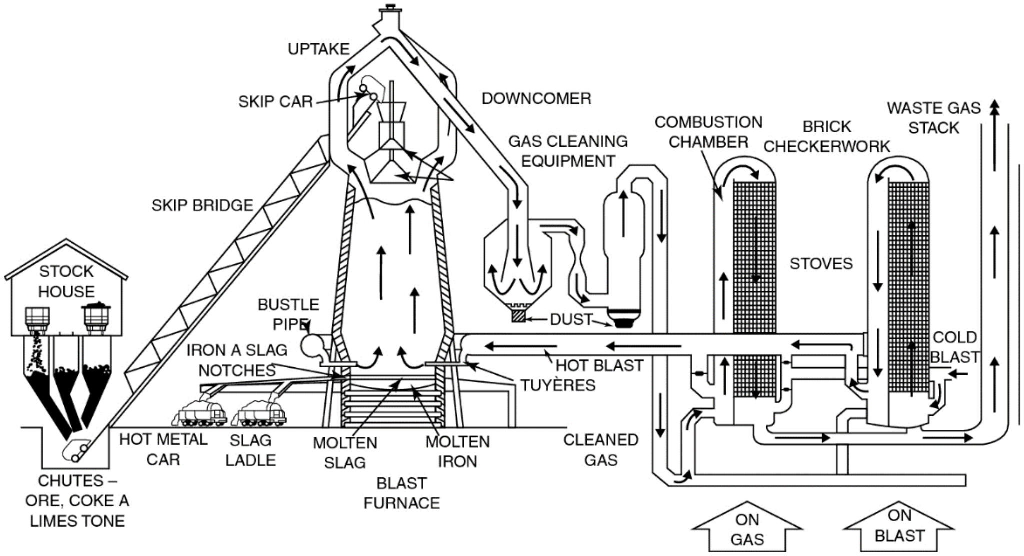

Figure: Blast furnace diagram. Source: Dutta S.K., Chokshi Y.B. (2020) Blast Furnace Process. In: Basic Concepts of Iron and Steel Making. Springer, Singapore. https://doi.org/10.1007/978-981-15-2437-0_2

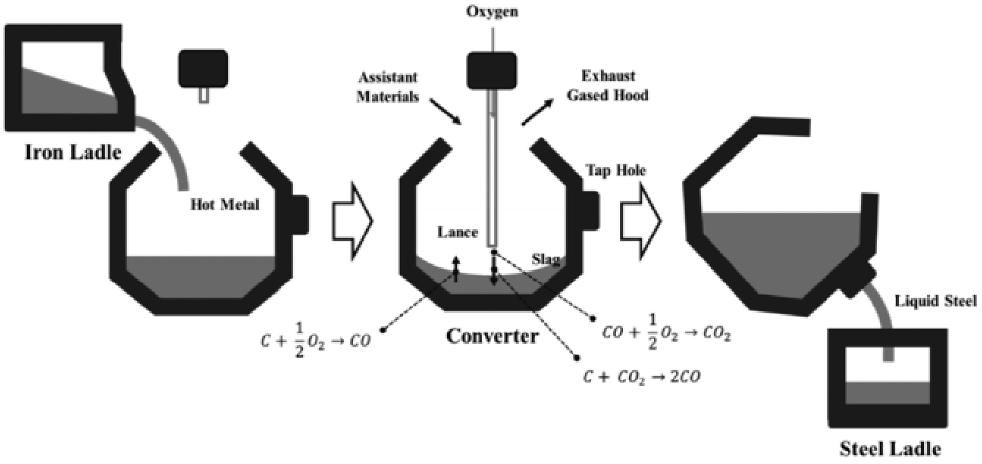

Figure: Basic oxygen furnace diagram. Source: Park, Tae & Kim, Beom & Kim, Tae & Jin, Il & Yeo, Yeong. (2018). Comparative Study of Estimation Methods of the Endpoint Temperature in Basic Oxygen Furnace Steelmaking Process with Selection of Input Parameters. Korean Journal of Metals and Materials. 56. 813-821. 10.3365/KJMM.2018.56.11.813.

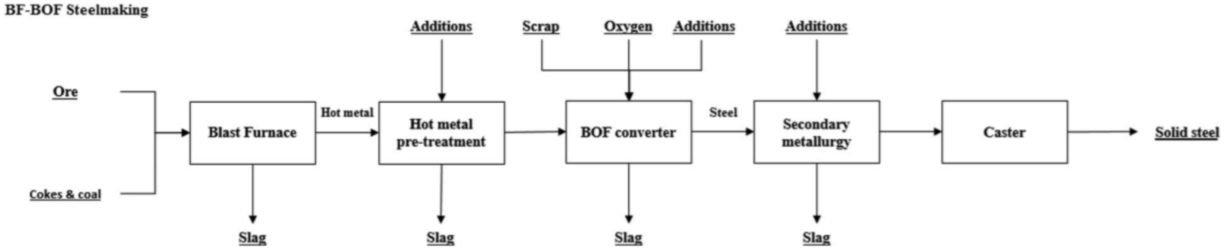

Figure: Flow of processes from ironmaking to steelmaking to ferroalloy ”additions”. Source: Frank Nicolaas Hermanus Schrama, Elisabeth Maria Beunder, Bart Vanden Berg, Yongxiang Yang & Rob Boom (2017) Sulphur removal in ironmaking and oxygen steelmaking, Ironmaking & Steelmaking, 44:5, 333-343, DOI: 10.1080/03019233.2017.1303914

Federal Rules Affecting Iron and Steel Mills and Ferroalloy Manufacturing

Iron and steel manufacturing facilities are subject to the NESHAP for Integrated Iron and Steel Manufacturing Facilities (40 CFR Part 63 Subpart FFFFF) and NESHAPs for Iron and Steel Foundries (40 CFR Part 63 Subpart EEEEE). 40 CFR Part 60 Subpart AA – AAa contains NSPS for Electric Arc Furnaces (EAFs) and Argon-Oxygen Decarburization Vessels (AOD). BOFs are regulated under the NSPS for Basic Oxygen Process Furnace (BOPF) Primary Emissions, codified at 40 CFR Part 60 Subpart N, and secondary BOF emissions are regulated under 40 CFR Part 60 Subpart Na. Open-pit mines are subject to the Standards of Performance for Metallic Mineral Processing Plants (40 CFR Part 60 Subpart LL) and taconite facilities are subject to the NESHAPs for Taconite Iron Ore Processing (40 CFR Part 63 Subpart RRRRR). 40 CFR Part 61 Subpart L contains NESHAPs for Benzene Emissions from Coke By-Product Recovery Plants, and coke ovens are subject to 40 CFR Part 63 Subpart CCCCC, NESHAPs for Coke Ovens: Pushing, Quenching, and Battery Stacks. 40 CFR Part 713 establishes reporting requirements for Mercury that apply to iron and steel mill and ferroalloy manufacturing, to satisfy the Toxic Substances Control Act (TSCA). Iron and steel production contributes to a considerable portion of the anthropogenic atmospheric mercury emissions worldwide. Iron, Steel Mills and Ferroalloy manufacturing is also subject to the continuous emission monitoring requirements of 40 CFR Part 75 and the iron and steel manufacturing point source category requirements of 40 CFR Part 420, with subcategories for sintering, ironmaking, cokemaking, steel making, vacuum degassing etc, based on NSPS, best available technology (BAT) and other federal limit applications to effluent in this industry. 40 CFR Part 424 contains the point source category regulations for ferroalloy manufacturing. 40 CFR Part 98 – Mandatory Greenhouse Gas Reporting – contains subpart F, K, and Q with requirements for aluminum production, ferroalloy production, iron and steel production, respectively.

Technology-Based Federal Regulations

The NESHAPs for Integrated Iron and Steel Manufacturing Facilities (40 CFR Part 63 Subpart FFFFF) were promulgated in 2003 (68 FR 27646) and amended in 2006 (71 FR 39579) to include a new compliance option, revised emission limitations, modified performance testing for certain emission units, added corrective action requirements, and clarified monitoring, recordkeeping and reporting requirements. The NESHAPs for Iron and Steel Foundries (40 CFR Part 63 Subpart EEEEE) were promulgated April 22, 2004 (69 FR 21923) and amended in 2008

(73 FR 7210) and 2020 (85 FR 56080). The 2008 amendments similarly added new compliance options at existing foundries and clarified certain operational flexibility provisions. However, in 2020 EPA conducted a risk and technology review of the standards concluding that no new cost-effective controls for major or area sources are available and, thus, did not make any substantive changes to the standards. The 2020 amendments removed exemptions for periods of startup, shutdown, and malfunction, and revised the monitoring, recordkeeping and reporting elements to establish electronic performance test results.

CAA Section 112(d) is satisfied by implementing maximum achievable control technology (MACT) standards expressed as emissions limits by source category based on emissions levels currently being achieved by the most efficient, lower-emitting and efficiently controlled sources. Generally available control technology (GACT) standards are established for area sources with less stringency than MACT standards These standards are re-evaluated every eight years to assess health risks. Amendments to the national emission standards for coke oven batteries were proposed August 9, 2004 (69 FR 48338) that included more stringent requirements for certain by-product coke oven batteries to address health risks remaining after implementation of the 1993 national emission standards. The updated MACT standards were finalized April 15, 2005 (70 FR 19992), and existing sources were required to comply by July 14, 2005.

NOx Controls

In iron and steel production, three different mechanisms yield three different types of NOx: thermal NOx, fuel NOx, and prompt NOx.[34] NOx formation is dependent on "the efficiency of the plant, on the nitrogen content of the fuel, and on the related oxygen content in the waste gas."[35] Thermal NOx forms during high-temperature combustion processes by oxidation of nitrogen, fuel NOx through oxidation of the fuel-bound nitrogen, and prompt NOx from the oxidation of the intermediate compound, hydrogen cyanide (HCN).[36] The formation of thermal and fuel NOx can be distinguished depending on temperature and concentration, dwell time and type of fuel. The formation of thermal NOx starts at 1300 °C and rises greatly with an increasing temperature.[37]

EPA's Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills provides data on uncontrolled NOx emissions from specific iron and steel process facilities.

Uncontrolled NOx emissions from Coke Plants

	ppm @ 3% O_2	lb/MMBtu	lb/ton
n (No. Samples)	8	11	12
Min. Value	254	0.10	0.15

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[34] EPA, "Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills," EPA-453/R-94-065 (September 1994), at 2-4.

[35] Joint Research Centre of the European Commission, "Best Available Techniques (BAT) Reference Document for Iron and Steel Production," Industrial Emissions Directive 2010/75/EU (2013), at 32.

[36] EPA, "Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills," EPA-453/R-94-065 (September 1994), at 2-4.

[37] Joint Research Centre of the European Commission, "Best Available Techniques (BAT) Reference Document for Iron and Steel Production," Industrial Emissions Directive 2010/75/EU (2013), at 32.

Max. Value	1452	2.06	2.15
Avg. Value	802	0.66	0.88
Std. Dev.	448	0.72	0.64

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-11.

Uncontrolled NOx emissions from Blast Furnaces and Blast Furnace Stoves

	ppm @ 3% O_2	lb/MMBtu	lb/ton
n (No. Samples)	1	11	10
Min. Value		0.002	0.003
Max. Value		0.057	0.072
Avg. Value	28	0.021	0.037
Std. Dev.		0.019	0.022

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-12.

Uncontrolled NOx emissions from Basic Oxygen Furnace

During O_2 Blow Period

	ppm (avg)	ppm @ 3% O_2	lb/ton
n (No. Samples)	12	7	7
Min. Value	12.3	18	0.042
Max. Value	84.0	180	0.222
Avg. Value	24.0	58	0.119
Std. Dev.	19.6	56	0.059

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-13.

During Non O_2 Blow Period

	ppm (avg)	ppm @ 3% O_2	lb/ton
n (No. Samples)	2	2	-
Min. Value	14.3	200	-
Max. Value	14.5	366	-
Avg. Value	14.4	283	-

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-13.

Uncontrolled NOx emissions from Electric-Arc Furnace

EAF With Concurrent Oxy-fuel Firing

	ppm (avg)	lb/ton	lb/heat
n (No. Samples)	6	6	6
Min. Value	80	0.50	83
Max. Value	110	0.60	100
Avg. Value	98	0.54	89
Std. Dev.	10	0.05	8.2

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-14.

EAF Without Concurrent Oxy-fuel Firing

	ppm (avg)

n (No. Samples)	2
Min. Value	7
Max. Value	17
Avg. Value	12

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-14.

Uncontrolled NOx emissions from Reheat Furnaces

	lb/MMBtu	ppm @ 3% O_2	lb/ton
n (No. Samples)	28	14	11
Min. Value	0.023	65	0.054
Max. Value	0.909	740	0.327
Avg. Value	0.226	292	0.198
Std. Dev.	0.198	166	0.084

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 4-16.

For the iron and steel mills source category, the NACAA (formerly STAPPA/ALAPCO) has recommended requiring emission “reductions from reheat furnaces using low NOx burners (LNB) and flued gas recirculation (FGR) (to achieve reductions of 50 percent or more), from annealing furnaces using SCR and low NOx burners (to achieve reductions of 95 percent or more) and from galvanizing furnaces using low NOx burners and FGR (to achieve reductions of 75 percent or more).”[38] LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. FGR includes the recirculation of cooled flue gas, which reduces temperature by diluting the oxygen content of combustion air and by causing heat to be diluted in a greater mass of flue gas. The reduction of temperature lowers the NOx concentration that is generated. More specifically, the use of Selective Catalytic Reduction (SCR) with LNB is recommended for annealing furnaces, and LNB with FGR is recommended for galvanizing furnaces.

SCR is a process that uses ammonia in the presence of a catalyst to selectively reduce NOx emissions from exhaust gases. This technology, at first, was widely used for NOx reduction in other industries, such as coal-fired power stations and waste incinerators. In SCR, anhydrous ammonia, usually diluted with air or steam, is injected through a grid system into hot flue gases which are then passed through a catalyst bed to carry out NOx reduction reactions. As ammonia is injected into the flue gas, it is converted to NOx, molecular nitrogen (N_2) and water (H_20). To prevent ammonia salt formation, which can lead to salt blocking the catalyst, a temperature of at least 320 °C is required. Because 90% of the NOx in flue gas from coal-fired boilers is nitric oxide (NO), a molar ratio of NH3 to NOx of approximately 1:1 is needed to maximize NOx removal and reduce the amount of unreacted ammonia emissions. The figure below shows the typical configuration of a catalytic NOx converter.[39] Three SCR systems can be considered

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[38] STAPPA/ALAPCO, Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options, 78-79 (July 1994).

[39] Joint Research Centre, Institute for Prospective Technological Studies, Remus, R., Roudier, S., Delgado Sancho, L., et al., *Best available techniques (BAT) reference document for iron and steel production : industrial emissions Directive 2010/75/EU : integrated pollution prevention and control*, Publications Office (2013), available at https://op.europa.eu/en/publication-detail/-/publication/eaa047e8-644c-4149-bdcb-9dde79c64a12/language-en.

depending on the placement of the control: low dust exhaust gas, high dust exhaust gas and tail end gas treatment. The high dust gas treatment places the SCR between the economizer and the air preheater and is the most common placement because it eliminates the need to re-heat flue gas to the desired temperature.[40] Low dust and tail-end exhaust gas systems require reheating of the exhaust gases after dedusting, resulting in additional cost.

In the Steel, Iron and Ferroalloy Sector, the combination of LNBs and SCR has been shown to be capable of achieving up to 90 percent reduction of NOx emissions from annealing furnaces and 80 percent when SNCR is used in conjunction with LNBs.[41] SCR alone was found to achieve 85 percent NOx emission reductions when firing an annealing furnace by coal[41]. FGR used in conjunction with LNBs was shown to achieve 77 percent reduction of NOx emissions on reheat furnaces and 60 percent on galvanizing furnaces [41].

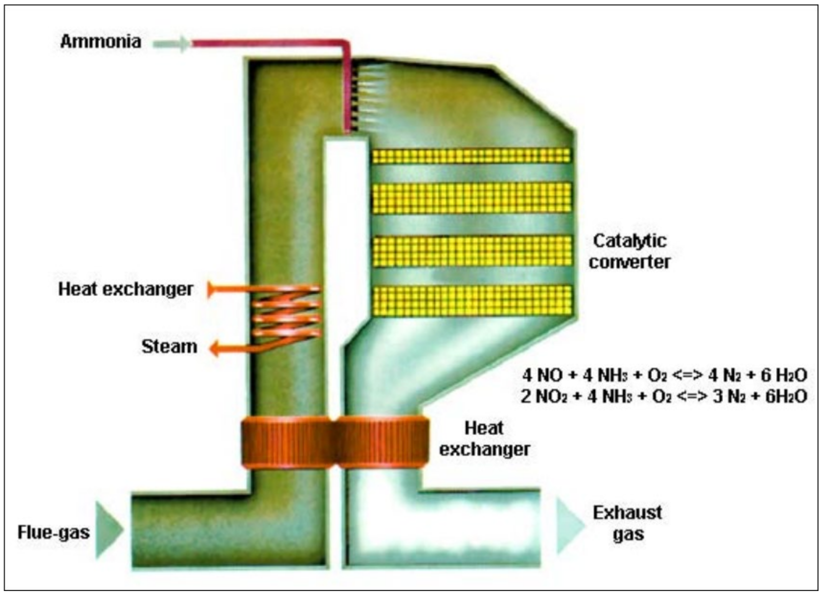

Figure: Catalytic NOx converter

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[40] *See* Schreifels, Jeremy & Wang, Shuxiao & Hao, Jiming, Design and Operational Considerations for Selective Catalytic Reduction Technologies at Coal-fired Boilers, Frontiers of Energy and Power Engineering in China, 6. 98-105. 10.1007/s11708-012-0171-4 (2012).

[41] *See* EPA, Nitrogen oxides: Why and How they are Controlled, Clean Air Technology Center (MD-12), Technical Bulletin No. EPA-456/F-99-006R (1999), available at http://www. epa. gov/ttncatc1/dir1/fnoxdoc.pdf.

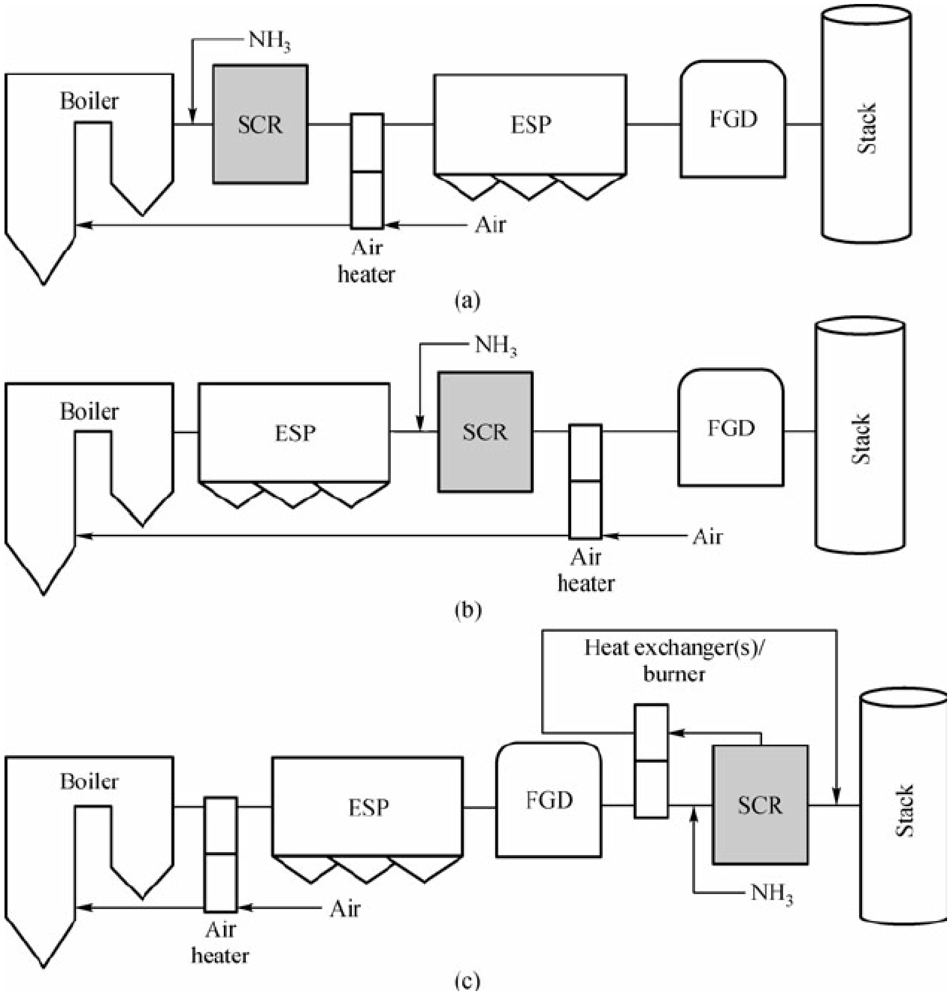

Figure: High dust (a), low dust (b) and tail end (c) techniques for SCR placement. Source: Schreifels, Jeremy & Wang, Shuxiao & Hao, Jiming. (2012). Design and operational considerations for selective catalytic reduction technologies at coal-fired boilers. Frontiers of Energy and Power Engineering in China. 6. 98-105. 10.1007/s11708-012-0171-4.

Selective non-catalytic reduction (SNCR) is another post-combustion control technique used in many industries to reduce NOx emissions. SNCR differs from SCR in that it does not require a catalyst, but the absence of catalyst allows for NOx control at higher operating temperatures, in some cases in the range of 900 to 1000 °C. Similar to SCR, the process involves the conversion of NOx to molecular nitrogen and H20 by injecting ammonia into the flue gas. In this system, optimal temperature is important, as temperatures above the upper range lead to increased NOx formation and temperatures below the lower range lead to ammonia slip[42] For annealing furnaces, SNCR has been shown to reduce NOx emissions by 60 percent[43] and when used in

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[42] *See* Mukhtar, Umar Alhaji et al. "NOx Emission in Iron and Steel Production: A Review of Control Measures for Safe and Eco-Friendly Environment." Arid Zone Journal of Engineering, Technology and Environment 13 (2017): 848-857.

[43] *See* EPA, Alternative control techniques document report for emissions from iron and steel mills, Office of Air Quality Planning and Standard, Research triangular park, EPA-453/R-94-065 (1994).

conjunction with LNBs, SNCR has been shown to reduce NOx emissions by 89 percent for oil and gas fired units and 80 percent for coal fired units.[44]

The table below summarizes controlled NOx emissions data and estimates and potential percent reductions for reheat furnaces and annealing furnaces.

Furnace Type	Control	Emissions (lb/MMBtu) Regenerative	Emissions (lb/MMBtu) Recuperative	Emissions (lb/MMBtu) Cold-Air	Percent Reduction
Reheat	LNB	0.27	0.068	0.046	66
	LNB + FGR	0.18	0.046	0.031	77
Annealing	LNB	0.48	0.20	0.07	50
	LNB + FGR	0.38	0.16	0.07	60
	SNCR	0.38	0.16	0.07	60
	SCR	0.14	0.06	0.02	85
	LNB + SNCR	0.19	0.08	0.03	80
	LNB + SCR	0.095	0.04	0.015	90

Reproduced from EPA, “Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills,” EPA-453/R-94-065 (September 1994), at 2-8.

The European Union Commission charged with establishing Best Available Techniques (BAT) to control NOx emissions from iron and steel production describes control techniques for select emission units associated with iron and steel production.

For Coke Oven Plants, BAT to reduce emissions includes incorporating low-nitrogen oxides techniques in construction of new batteries (only applicable to new plants). The BAT-associated emission level for nitrogen oxides is 350 – 500 mg/Nm3 for new or substantially revamped plants (less than 10 years old) and 500 – 650 mg/Nm3 for older plants with well-maintained batteries and incorporated low- nitrogen oxides (NOx) techniques.[45]

For Blast Furnaces, BAT is to reduce emissions by using desulphurised and dedusted surplus coke oven gas, dedusted blast furnace gas, dedusted basic oxygen furnace gas and natural gas, individually or in combination. BAT-associated emissions levels for nitrogen oxides are 100 mg/Nm3.[46]

The European Integrated Pollution Prevention and Control Bureau (EIPPCB) at the European Commission's Joint Research Centre – Institute for Prospective Technological Studies (IPTS) created a reference document in the framework of the implementation of the aforementioned

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[44] Midwest Regional Planning Organization (MRPO). 2005. Iron and Steel Mills Best Available Retrofit Technology (BART) Engineering Analysis.

[45] Official Journal of European Union Commission, Best Available Techniques (BAT) Conclusions Under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for Iron and Steel Production, (February 28, 2012), Section 1.4.49.

[46] Official Journal of European Union Commission, Best Available Techniques (BAT) Conclusions Under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for Iron and Steel Production, (February 28, 2012), Section 1.5.65.

Industrial Emissions Directive (2010/75/EU) that describes the general primary and secondary methods for reducing NOx emissions from iron and steel production.

These measures can be applied individually or in combination. Injection of reduction fuel, such as a mixture of recycled exhaust gas and natural gas, between the last burner level and the upper air can reduce NOx but is not efficient in combination with the usage of low-NOx burners at the same time. Air and fuel staging can be used to influence the size of the combustion area and the dwell time in the flame and these staging methods yield similar NOx reductions.[47] The NOx reduction efficiencies of the aforementioned measures are summarized below.

Applied primary measure	**NOx reduction efficiency (%)**
Low-NOx burner	28
Flue-gas recirculation	13
Upper air injection for residual combustion with sub-stoichiometric burners	23
Injection of reduction fuel	13
Low-NOx burner plus flue-gas recirculation	38

Reproduced from Joint Research Centre of the European Commission, "Best Available Techniques (BAT) Reference Document for Iron and Steel Production," Industrial Emissions Directive 2010/75/EU (2013), at 60, 62.

This report also describes measures for reducing NOx at certain sources. For Coke Plants, the European Commission identified flame temperature reduction in the heating chamber as the most effective way of reducing NOx formation. Three effective methods are listed: waste gas recirculation to reduce the flame temperature, staged air combustion to make combustion conditions more moderate, and lowering of coking temperatures which requires a lower heating chamber temperature. Additionally, structural changes can be made to the heating chamber to improve thermal conductivity, such as using thinner bricks, which reduces the heating chamber temperature and therefore reduces NOx formation.[48]

EPA's Alternative Control Techniques Document for NOx Emissions from Iron and Steel[49] notes that while Coke ovens are among the major NOx emission sources at iron and steel mills, coke ovens with NOx controls in the United States have not been found. The document instead cites the Japan Iron and Steel Federation's report of installation of SCR units on coke ovens. The report also identifies low-air-ratio combustion, denitrification, and flue-gas recirculation of fuel as NOx control techniques applicable to coke ovens.[50]

EPA's Menu of Control Measures (MCM) provides state, local and tribal air agencies with information on existing criteria pollutant emission reduction measures as well as relevant

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[47] Joint Research Centre of the European Commission, "Best Available Techniques (BAT) Reference Document for Iron and Steel Production," Industrial Emissions Directive 2010/75/EU (2013), at 59-60.

[48] Joint Research Centre of the European Commission, "Best Available Techniques (BAT) Reference Document for Iron and Steel Production," Industrial Emissions Directive 2010/75/EU (2013), at 257.

[49] EPA, "Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills," EPA-453/R-94-065 (September 1994).

[50] EPA, "Alternative Control Techniques Document – NOx Emissions from Iron and Steel Mills," EPA-453/R-94-065 (September 1994), at 5-19.

information concerning the efficiency and cost effectiveness of the measures.[51] State, local, and tribal agencies may use this information in developing emission reduction strategies, plans and programs to assure they attain and maintain the NAAQS. For NOx emission control from iron and steel operations the MCM's control measures are tabulated on the subsequent pages.

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[51] EPA, Menu of Control Measures for NAAQS Implementation, available at https://www.epa.gov/air-quality-implementation-plans/menu-control-measures-naaqs-implementation (URL dated January 5, 2022).

Source Category	**Emission Reduction Measure**	**Control Efficiency (%)**	**Description/Notes/Caveats**	**References**
Iron & Steel - In-Process Combustion - Bituminous Coal	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Bituminous Coal) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
Iron & Steel - In-Process Combustion - Natural Gas and Process Gas - Coke Oven Gas	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to operations with in-process combustion (Natural Gas or Coke Oven Process Gas) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
Iron & Steel - In-Process Combustion - Natural Gas and Process Gas - Coke Oven Gas	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Natural Gas and Process Gas - Coke Oven Gas) in the Iron & Steel industry.	EPA 2010b
Iron & Steel - In-Process Combustion -	Low NOx Burner and	55	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel	EPA 2010b

Process Gas - Blast Furnace Stoves	Flue Gas Recirculation		nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to operations with in-process combustion (Process Gas - Coke Oven/ Blast Furnace) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	
Iron & Steel - In-Process Combustion - Residual Oil	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to operations with in-process combustion (Residual Oil) in the Iron & Steel industry with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2010b
Iron & Steel Mills - Annealing	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills - Annealing	Low NOx Burner and Flue Gas Recirculation	60	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills – Annealing	Low NOx Burner and Selective	90	This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between	EPA 2006b, Pechan 2001, EPA 1998e, EPA

	Catalytic Reduction		fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	2002a, EPA 1994e
Iron & Steel Mills – Annealing	Low NOx Burner and Selective Non Catalytic Reduction	80	This control is the use of low NOx burner (LNB) technology and selective catalytic reduction (SCR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control is applicable to iron and steel annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills - Annealing	Selective Catalytic Reduction	90-99	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water vapor (H_2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to iron and steel annealing operations with NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1993c, EPA 2007d, Sorrels 2007
Iron & Steel Mills – Annealing	Selective Non Catalytic Reduction	60	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N_2) and water	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA

			vapor (H2O). This control applies to iron and steel mill annealing operations with uncontrolled NOx emissions greater than 10 tons per year.	1994e, EPA 1993c
Iron & Steel Mills - Cupola Melt Furnaces	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to NOx emissions from the cupola melt furnaces at iron and steel operations.	RTI 2011
Iron & Steel Mills - Galvanizing	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel galvanizing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills - Galvanizing	Low NOx Burner and Flue Gas Recirculation	60	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel galvanizing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills – Reheating	Low Excess Air	13	The reduction in NOx emissions is achieved through the use of low excess air techniques, such that there is less available oxygen convert fuel nitrogen to NOx. This control applies to iron & steel reheating furnaces.	EPA 2006b, EPA 1993a, Pechan 2001, EPA 1998e, EPA 1994e, ERG 2000

Iron & Steel Mills – Reheating	Low NOx Burner	66	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to iron and steel reheating operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron & Steel Mills – Reheating	Low NOx Burner and Flue Gas Recirculation	77	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to reheating processes in iron and steel mills with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994e
Iron Production - Blast Furnace - Blast Heating Stoves	Low NOx Burner and Flue Gas Recirculation	77	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to reheating processes in iron production operations with blast heating stoves and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994e

State RACT Rules

Ohio NOx RACT rules limit NOx emissions from blast furnaces to 0.06 lb/mmBtu without requiring specific control technology.

Sterling Steel permit, issued 2019: Low-NOx natural gas fired burners designed to emit no more than 0.073 lb NOx/mmBtu, Ohio RACT limit is 0.09 lb/mmBtu

On and after July 18, 2013, "Charter Steel" or any subsequent owner or operator of the “Charter Steel” facility NOx emissions for bar mill reheat furnace PO29, rated at 165.0 mmBtu/hr, shall not exceed 0.11 lb/mmBtu.

United States Steel Lorain Tubular Operations has NOx emission limitations from the Ohio NOx RACT rules ranging from 0.068-0.15 lb/mmBtu for the five reheating furnaces at the facility.

Nucor Kankakee BACT permit limit issued January 2021 limit NOx emissions from ladle preheaters to 0.1 lb/mmBtu, 2021.

Ohio NOx RACT rules limit NOx emissions from Cleveland-Cliffs Inc ladle preheaters to 0.1 lb/mmbtu.

Ohio NOx RACT rules limit NOx emissions from reheat furnaces not subject to source-specific NOx limits to 0.09 lbs/mmbtu.

Ohio NOx RACT rules limit NOx emissions at Cleveland-Cliffs Inc annealing furnaces to 0.1 lb/mmbtu. Permit limits for Nucor, AR, was 0.0915 lb/mmBtu.

Cleveland-Cliffs Inc. in Ohio has a source specific NOx emission limitation of 0.06 lb/mmBtu for Blast Furnace Stoves. Also, for “basic oxygen furnaces (BOF),” there is a NOx emission limitation of 0.1 lb/mmBtu[52] contained in the Ohio NOx RACT rules.

Wisconsin’s NR 428.22(1)(c)(c), Subchapter IV – NOX Reasonably Available Control Technology Requirements[53] establishes limits for a reheat, annealing or galvanizing furnace with a maximum heat input capacity equal to or greater than 75 mmBtu/hr and 0.08 lb/mmBtu.

Pennsylvania’s RACT II rule[54] created to satisfy the 2008 National Ambient Air Quality Standards (NAAQS) for ozone, set NOx emission limits for Cleveland Cliffs Steel Corporation/Butler Works, previously AK Steel Corporation of 0.036 lb/mmBtu for the main plant boiler.

Emission Limits and Compliance Requirements in the Proposed Rule

In setting a NOx emission limit for blast furnaces, EPA considered a range of emission rates from 0.02 lb/mmBtu to 0.05 lb/mmBtu as calculated based on potential use of low-NOx burners, flue gas recirculation, and SCR. EPA notes that it has approved an Ohio SIP rule of 0.06

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[52] *See* paragraph N, https://codes.ohio.gov/ohio-administrative-code/rule-3745-110-03

[53] *See* https://docs.legis.wisconsin.gov/code/admin_code/nr/400/428/iv/20

[54] *See* https://www.dep.pa.gov/About/Regional/NorthwestRegion/Community-Information/Pages/RACT-II.aspx

lb/mmBtu without specifically requiring use of NOx-reducing control technology. *See* OAC 3745-110-03(N). Use of these technologies separately or in combination can achieve 20-90% reduction efficiency at blast furnace stoves. In this rulemaking, EPA is requiring each facility to tailor its NOx reduction technology to meet a NOx limit of 0.03 lb/mmBtu.

For basic oxygen furnaces, EPA based the emission limit of 0.07 lb/ton of steel on performance testing data from basic oxygen furnaces without NOx reduction controls at integrated iron and steel mills in the United States. EPA projects minimally 50% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of FGR and selective catalytic reduction. Most BOF vessels and associated BOF Shops in the United States are equipped with capture technology and existing particulate matter control devices. The existing configurations of these shops would accommodate the addition of NOx controls or additional design of a capture system capable of integrating such technology with these structures.

For vacuum degassers utilized in secondary steelmaking, EPA based the limit of 0.03 lb/mmBtu on existing permit limits of 0.05 lb/mmBtu. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including use of selective catalytic reduction.

For ladle and tundish preheaters, EPA based the emission limit of 0.06 lb/mmBtu on existing permit limits. The majority of recently issued permits limit NOx emissions from ladle and tundish preheaters to 0.1 lb/mmBtu based on prevailing operating rates compared to natural gas usage. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of low-NOx burners and selective catalytic reduction.

For EAFs, EPA based the emission limit of 0.15 lb/ton of steel on projected reduction efficiency of 40-50% as compared to existing permit limits for EAFs. EPA considered a range of baseline emission data and permit limits from mini mills, integrated iron and steel facilities, and ferroalloy facilities ranging from 0.20 lb/ton to 0.35 lb/ton. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of low-NOx burners and selective catalytic reduction.

For LMFs, EPA based the emission limit of 0.1 lb/ton of steel on projected reduction efficiency of 40-50% as compared to existing permit limits for LMFs. EPA considered a range of baseline emission data and current permit limits from 0.20 lb/ton to 0.35 lb/ton. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of low-NOx burners and selective catalytic reduction.

For reheat furnaces, EPA based the emission limit of 0.05 lb/mmBtu on projected reduction efficiency of 40-50% based on sampled operating and emission rates compared to natural gas usage. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of newer generation low-NOx burners or optimization of existing burners.

For annealing furnaces, EPA based the emission limit of 0.06 lb/mmBtu on projected reduction efficiency of 40-50% based on current permit emission limits and operating rates compared to natural gas usage. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of newer generation low-NOx burners or optimization of existing burners, or combination of low-NOx burners, flue gas recirculation, and/or selective catalytic reduction.

For taconite production kilns, EPA requires work practice standards that mirror requirements from the 2013 and 2016 Minnesota Regional Haze Taconite Federal Implementation Plans. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx technology, including potential use of newer generation low-NOx burners or optimization of existing burners.

For coke ovens (charging) and coke ovens (pushing), EPA based the emission limit of 0.15 lb/ton for charging and 0.015 lb/ton for pushing on projected reduction efficiency of 40-50% based on current permit emission limits and production-based push/charge cycles. EPA projects minimally 40% NOx reduction efficiency is achievable by use of low-NOx practices, staged pushing and hood configurations, and potential use of add-on NOx control technology at larry cars and pushing/charging machines, including potential use of low-NOx burners, flue gas recirculation, and/or the addition of selective catalytic reduction to mobile hoods and particulate matter control devices.

For boilers, EPA based emission limits of 0.2 lb/mmBtu for coal and residual oil boilers, 0.18 lb/mmBtu for distillate oil boilers, and 0.08 lb/mmBtu for natural gas boilers on existing RACT and BACT rules. EPA projects minimally 20% NOx reduction efficiency is achievable by use and optimization of low-NOx burners, flue gas recirculation, and/or the addition of selective catalytic reduction to existing capture and control systems.

Performance Test and Monitoring

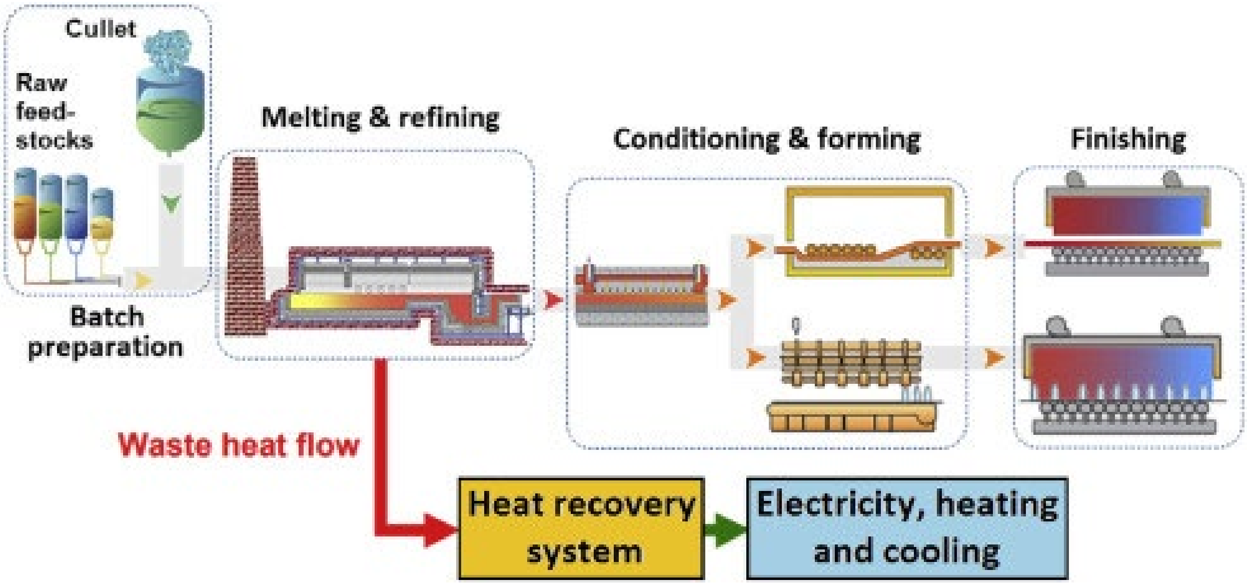
EPA is specifically proposing to require each owner or operator of an affected unit to install, calibrate, maintain, and operate a CEMS for the measurement of NOx emissions discharged into the atmosphere from the affected unit or shop, as applicable. EPA is soliciting comments on alternative monitoring systems and methods that are equivalent to CEMS to demonstrate compliance with the emission limits

5 Glass and Glass Product Manufacturing

Process Description[55]

Commercially produced glass can be classified as soda-lime, lead, fused silica, borosilicate, or 96 percent silica. Soda-lime glass consists of sand, limestone, soda ash, and cullet. Glass products are classified by both chemical composition and by the type of product produced. The main product types are flat glass, container glass, pressed and blown glass, and fiberglass. The manufacturing of such glass occurs in four phases: (1) preparation of raw material, (2) melting in the furnace, (3) forming and (4) finishing. The procedures for manufacturing these types of glass are the same for all products except for the forming and finishing process. Container glass and pressed/blown glass use pressing, blowing or pressing and blowing to form the desired product. Flat glass, which is the remainder, is formed by float, drawing, or rolling processes. The North American Industry Classification System (NAICS) code for glass and glass product manufacturing is 3272.

A diagram of a typical glass manufacturing process is shown below.



Reproduced from Andriy Redko, et al, "Glass Manufacture, Industrial waste heat resources," *ScienceDirect* (2020), Fig. 9.26, available at https://www.sciencedirect.com/topics/engineering/glass-manufacture.

Glass Melting Furnace

Glass melting furnaces are used by the glass industry in the production of glass. The glass melting furnaces contribute to most of the total emissions from the glass plant. Essentially all of the Oxides of Nitrogen (NOx) emissions associated with glass manufacturing are generated in

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[55] See generally EPA, AP-42 Compilation of Air Emissions Factors, Mineral Products Industry, Chapter 11, Mineral Products Industry, Section 11.15, Glass Manufacturing, Final Section (October 1986, reformatted January 1995).

the melting furnaces due to the high process temperatures. Nitrogen oxides form when nitrogen and oxygen react in the high temperatures of the furnace.

To manufacture glass, raw materials such as sand, limestone, soda ash, and cullet are crushed, mixed, and fed into the furnace. These materials are then heated in the furnace to temperatures around 3000°F to induce fusion which produces molten glass. After molten glass is produced, it then goes to be shaped by pressing, blowing, pressing and blowing, drawing, rolling, or floating to produce the desired product. The end products undergo finishing which include annealing, grinding, polishing, coating, and/or decorating. During the inspection process, any damaged or undesirable glass is transferred back to the batch plant to be used as cullet. Cullet is defined in EPA's NESHAP regulations as recycled glass that is mixed with raw materials and charged to a glass melting furnace to produce glass.[56]

Glass manufacturing furnaces can vary between the various categories of glass produced. This is because the different types of glass vary in composition and quality specifications. Therefore, each type of glass produced requires different energy inputs to fuse the raw materials. As a result, the emissions from similar furnaces producing different types of glass can vary significantly.

Nearly 50 percent of the glass manufacturing furnaces are a regenerative design, with two chambers containing refractory "checker bricks" for capturing heat. The flow of combustion air (influent) and flue gas (effluent) alternate passing through the checkers to recover heat and provide heat, respectively. Recuperative glass melting furnaces are also used which rely on heat exchanges to continuously preheat combustion air. Natural gas is commonly used as the source of heat from the industry. However, oil and electricity, as well as a combination of both, are also used.[57]

A diagram of a glass melting furnace is provided below.

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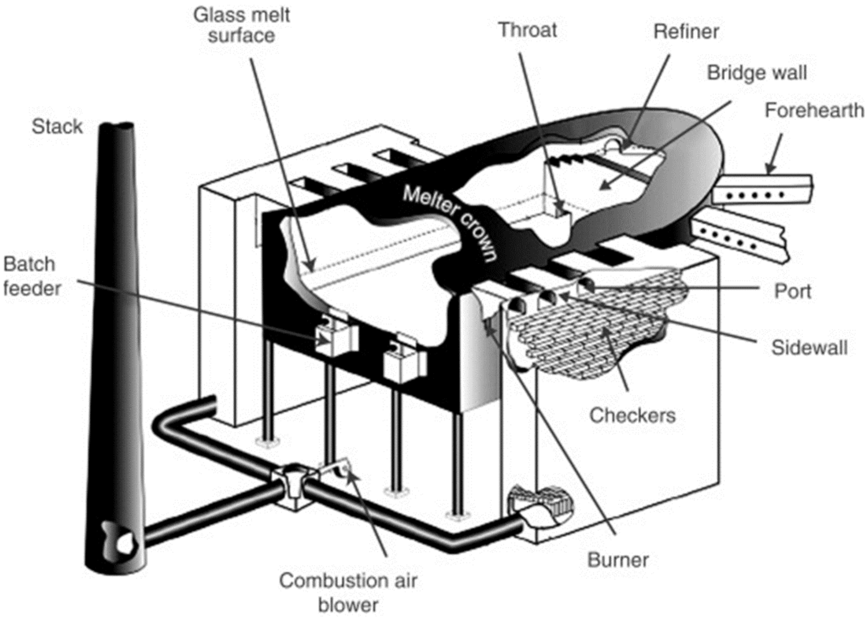
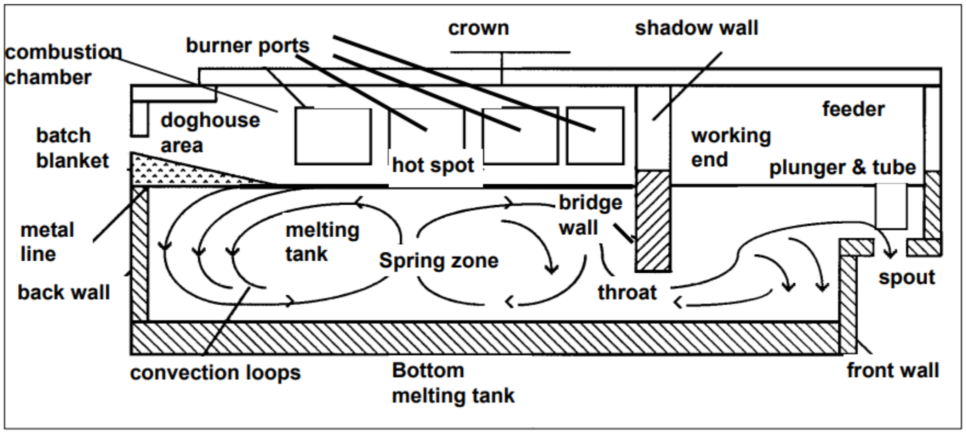
[56] See definitions in 40 CFR Part 63, Subpart SSSSSS, "National Emission Standards for Hazardous Air Pollutants for Glass Manufacturing Area Sources."

[57] Lake Michigan Air Directors Consortium (LADCO), Interim White Paper – Midwest RPO Candidate Control Measures, "Source Category: Glass Manufacturing" (December 2, 2005), available at https://www.ladco.org/wp-content/uploads/Documents/Reports/Control/white_papers/glass_fiberglass_manufacturing_plants.pdf



Reproduced from Ravi Jain, et al,"Glass Furnace, Energy and Environmental Implications," *ScienceDirect* (2012), available at https://www.sciencedirect.com/topics/engineering/glass-furnace.

The components of a continuous glass furnace are provided below.



Reproduced from Mathieu Hubert, PHD, et al, "IMI-NFG Course on Processing in Glass,"*LeHigh* (2015), available at https://www.lehigh.edu/imi/teched/GlassProcess/Lectures/Lecture03_Hubert_industglassmeltfurnaces.pdf.

The furnace operation is the main source of pollution at a glass manufacturing plant. The reaction of nitrogen and oxygen in the furnace creates NOx emissions. This occurs in the combustion zone and in the checkers in the production of flat glass furnace where temperatures can reach up to 2300°F. Particulate emissions result from the volatilization of materials that later form condensates and from material handling. Sulfur dioxide (SO2) emissions are the product of oxidation of sulfur containing compounds in fuels and in the raw materials formulations. VOC emissions may be associated with the use of lubricants, mold release agents and coating used in the decoration of finished products.

Federal Rules affecting Glass Plants

Glass plants are subject to the Glass Manufacturing NESHAP (40 CFR Part 63 Subpart SSSSSS) and NSPS (40 CFR Part 60 Subpart CC). Glass manufacturing furnaces that burn hazardous waste are subject to the Hazardous Waste Combustor NESHAP (40 CFR Part 63 Subpart SSSSSS).

Technology-Based Federal Regulations

The NSPS implementing Clean Air Act (CAA) section 111(b) for Glass Manufacturing Plants was first promulgated at 40 CFR part 60, Subpart CC on October 7, 1980 (45 FR 66751). EPA conducted three additional reviews of these standards on October 19, 1984 (49 FR 41030), February 14, 1989 (54 FR 6674), and October 17, 2000 (65 FR 61759). The NSPS applicable to the glass manufacturing industry only provides standards for particulate matter from sources and does not provide standards or averaging times for NOx.

NOx Controls

The NACAA (formerly STAPPA/ALAPCO) has recommended requiring "combustion modifications, process changes and post-combustion controls [Selective Non-Catalytic Reduction] (SNCR)" to limit NOx emissions from the glass furnaces source category.[58] SNCR is a post combustion control technology used to reduce NOx emissions without the presence of a catalyst. The NACAA has also noted that "RACT limits of 5.3-5.5 lbs NOx/ton of glass removed have been adopted, as well as limits as low as 4.0 lbs NOx/ton of glass removed" and recommended "[requiring] sources to coordinate installation of controls with routine furnace rebuilds to lower costs."[59]

The European Union Commission charged with establishing the Best Available Techniques (BAT) to control NOx emissions from the production of glass outlines the control techniques tabulated below.

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58 STAPPA/ALAPCO, Controlling Nitrogen Oxides Under the Clean Air Act: A Menu of Options, 78-79 (July 1994), available at https://p2infohouse.org/ref/02/01245/3017101.pdf.

[59] Id.

Primary Techniques/Measures	**Description**
Combustion Modifications	
(i) Reduction of air/fuel ratio	The technique is mainly based on the following features: - minimization of air leakages into the furnace - careful control of air used for combustion - modified design of the furnace combustion chamber
(ii) Reduced combustion air temperature	The use of recuperative furnaces, in place of regenerative furnaces, results in a reduced air preheat temperature and, consequently, a lower flame temperature. However, this is associated with a lower furnace efficiency (lower specific pull), lower fuel efficiency and higher fuel demand, resulting in potentially higher emissions (kg/ton of glass)
(iii) Staged combustion	- Air staging – involves sub-stoichiometric firing and the addition of the remaining air or oxygen into the furnace to complete combustion. - Fuel staging – a low impulse primary flame is developed in the port neck (10 % of total energy); a secondary flame covers the root of the primary flame reducing its core temperature
(iv) Flue-gas recirculation	Implies the reinjection of waste gas from the furnace into the flame to reduce the oxygen content and therefore the temperature of the flame. The use of special burners is based on internal recirculation of combustion gases which cool the root of the flames and reduce the oxygen content in the hottest part of the flames
(v) Low-NOx burners	The technique is based on the principles of reducing peak flame temperatures, delaying but completing the combustion and increasing the heat transfer (increased emissivity of the flame). It may be associated with a modified design of the furnace combustion chamber
(vi) Fuel choice	In general, oil-fired furnaces show lower NOx emissions than gas-fired furnaces due to better thermal emissivity and lower flame temperatures
Special furnace design	Recuperative type furnace that integrates various features, allowing for lower flame temperatures. The main features are: - specific type of burners (number and positioning) - modified geometry of the furnace (height and size) - two-stage raw material preheating with waste gases passing over the raw materials entering the furnace and an external cullet preheater downstream of the recuperator used for preheating the combustion air

Electric melting	The technique consists of a melting furnace where the energy is provided by resistive heating. The main features are: - electrodes are generally inserted at the bottom of the furnace (cold-top) - nitrates are often required in the batch composition of cold-top electric furnaces to provide the necessary oxidizing conditions for a stable, safe and efficient manufacturing process
Oxy-fuel melting	The technique involves the replacement of the combustion air with oxygen (>90% purity), with consequent elimination/reduction of thermal NOx formation from nitrogen entering the furnace. The residual nitrogen content in the furnace depends on the purity of the oxygen supplied, on the quality of the fuel (% N2 in natural gas) and on the potential air inlet
Chemical reduction by fuel	The technique is based on the injection of fossil fuel to the waste gas with chemical reduction of NOx to N2 through a series of reactions. In the 3R process (which is proprietary), the fuel (natural gas or oil) is injected at the regenerator entrance. The technology is designed for use in regenerative furnaces.
Selective catalytic reduction (SCR)	The technique is based on the reduction of NOx to nitrogen in a catalytic bed by reaction with ammonia (in general aqueous solution) at an optimum operating temperature of around 300 – 450 °C. One or two layers of catalyst may be applied. A higher NOX reduction is achieved with the use of higher amounts of catalyst (two layers)
Selective non-catalytic reduction (SNCR)	The technique is based on the reduction of NOx to nitrogen by reaction with ammonia or urea at a high temperature. The operating temperature window must be maintained between 900 and 1,050 °C
Minimizing the use of nitrates in the batch formulation	The minimization of nitrates is used to reduce NOx emissions deriving from the decomposition of these raw materials when applied as an oxidizing agent for very high quality products where a very colourless (clear) glass is required or for other glasses to provide the required characteristics. The following options may be applied: - Reduce the presence of nitrates in the batch formulation to the minimum commensurate with the product and melting requirements. - Substitute nitrates with alternative materials. Effective alternatives are sulphates, arsenic oxides, cerium oxide. - Apply process modifications (e.g. special oxidizing combustion conditions)

Reproduced from Official Journal of European Union Commission, Best Available Techniques (BAT) Conclusions Under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for the Manufacture of Glass, February 28, 2012, Table 1.10.2.

EPA's Menu of Control Measures (MCM) provides state, local and tribal air agencies with information on existing criteria pollutant emission reduction measures as well as relevant information concerning the efficiency and cost effectiveness of the measures. State, local, and tribal agencies may use this information in developing emission reduction strategies, plans and programs to assure they attain and maintain the NAAQS. The information from the MCM can also be found in the Control Measures Database (CMDB), a major input to the Control Strategy Tool (CoST), which EPA used in the NOx control strategy analysis included in the Non-EGU Screening Assessment memorandum.[60] Information about control measures to reduce NOx emissions from glass manufacturing operations is tabulated below.

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[60] EPA, Control Measures Database (CMDB) for Stationary Sources, available at https://www.epa.gov/system/files/other-files/2021-09/cmdb_2021-09-02_0.zip (URL dated January 6, 2022).

Source Category	Emission Reduction Measure	Control Efficiency (%)	Description/Notes/Caveats	References
Glass Manufacturing - Container	Cullet Preheat	25	This control is the use of cullet preheat technologies to reduce NOx emissions from glass manufacturing operations. This control is applicable to container glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
Glass Manufacturing - Container	Electric Boost	10	This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to container glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
Glass Manufacturing - Container	OXY-Firing	85	This control is the use of Oxy-firing in container glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing."	EPA 2006b
Glass Manufacturing - Container	Selective Catalytic Reduction	75	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to glass-container manufacturing processes with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f
Glass Manufacturing - Container	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emissions through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to glass-container manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
Glass Manufacturing - Container	Low NOx Burner	40	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of	EPA 2006b, EPA 1998e, EPA 2002a, EPA 1994f

			oxygen available in another. This control applies to flat glass and container glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	
Glass Manufacturing - Container	Electric Boost	10	This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to flat glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
Glass Manufacturing - Container	OXY-Firing	85	This control is the use of Oxy-firing in flat glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing."	EPA 2006b
Glass Manufacturing - Container or Flat Glass	Selective Catalytic Reduction	75	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to flat-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
Glass Manufacturing - Flat	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to flat-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
Glass Manufacturing - Flat	OXY-Firing	85	This control is the use of Oxy-firing in glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing."	EPA 2007b
Glass Manufacturing - Flat	Cullet Preheat	25	This control is the use of cullet preheat technologies to reduce NOx emissions from glass manufacturing operations. This control is applicable to pressed glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f

Glass Manufacturing - Flat	Electric Boost	10	This control is the use of electric boost technologies to reduce NOx emissions from glass manufacturing operations. This control applies to pressed glass manufacturing operations.	EPA 2006b, EPA 1998e, EPA 1994f
Glass Manufacturing - General	Low NOx Burner	40	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to pressed glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 1998e, EPA 2002a, EPA 1994f
Glass Manufacturing - Pressed	OXY-Firing	85	This control is the use of Oxy-firing in pressed glass manufacturing furnaces to reduce NOx emissions. Oxygen enrichment refers to the substitution of oxygen for nitrogen in the combustion air used to burn the fuel in a glass furnace. Oxygen enrichment above 90 percent is sometimes called "oxy-firing"	EPA 2006b
Glass Manufacturing - Pressed	Selective Catalytic Reduction	75	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to pressed-glass manufacturing operations, and uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c
Glass Manufacturing - Pressed	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emissions through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to pressed-glass manufacturing operations with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994f, EPA 1993c

Reproduced from EPA, Menu of Control Measures for NAAQS Implementation, available at https://www.epa.gov/air-quality-implementation-plans/menu-control-measures-naaqs-implementation (URL dated January 5, 2022)

In 1994, the Emission Standards Division of the Office of Air Quality Planning and Standards of the U.S. Environmental Protection Agency issued a report detailing alternative control techniques (ACTs) for NOx emissions from glass manufacturing facilities. The table below summarizes the NOx control technologies identified in EPA's ACT document for glass manufacturing.[61]Since 1994, the demand for flat, container, and pressed/blown glass has continued to increase annually.[62]To meet this demand, the glass manufacturing industry is has also continued to grow. The flat glass industry alone is expected to grow in 10 – 20% annually due to the increase of flat glass demands within the building construction and car manufacturing industry.[63] Nitrogen oxides remain to be one of the primary air pollutants produced during the production and manufacturing of glass products. However, current federal regulations only focus to control emissions of particulate matter, metals, and organic hazardous air pollutants. Currently, there is no NSPS that provides standards or averaging times for NOx from glass manufacturing furnaces. The growth of the glass manufacturing industry along with the continued absence of an NSPS that regulates NOx emission from the industry, calls for the need of NOx standards for this industry. However, over the last decades the glass industry has participated in various pollution prevention efforts including the 33/50 program, Green Lights and Energy Star programs.[64] Since 1994, various studies have been conducted by the glass manufacturing industries to help identify preferred techniques for the control of NOx. While these studies reveal some new trends in the glass industry, they generally reveal that the 1994 EPA report is still accurate.[65]

Technology	NOx Reduction (%)
Combustion modifications	
Low NOx burners	40
Oxy-firing	85
Process modifications	
Modified furnace	75
Cullet preheat	25
Electric boost	10
Post combustion modifications	
SCR	75
SNCR	40

State RACT Rules

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[61] EPA, Alternative Control Techniques Document— NOx Emissions from Glass Manufacturing, EPA-453/R-94-037 (June 1994) at 2-7.

[62] U.S. Department of Energy, Glass Industry of the Future – Energy and Environmental Profile of the U.S. Glass Industry, (April 2002), Pages 6 - 9.

[64] See *id.*

[65] The use of recycled glass (cullet) has also increased in practice within the glass manufacturing industry over the past decades. The use of cullet reduces the energy intensity needed to produce glass, therefore reducing emissions. Increased in energy efficiency has also been accomplished through improved control systems, the development and use of advanced refractory materials, and technologies such as oxy-firing and electric boost which increase production capacity.

Federal emission control regulations for glass manufacturing facilities historically focused on particulate and arsenic emissions. However, regulations for the control of NOx emissions have also been adopted in a few states. EPA reviewed various RACT NOx rules from states located within the Ozone Transport Region (OTR). EPA chose to review these RACT NOx rules because several OTR states implement Ozone Transport Commission (OTC) model rules and recommendations. During its review, EPA observed that most of the states within the OTR have adopted RACT regulations for the glass manufacturing sector that do not specify NOx limits.[66] Examples of OTR states that do not specify NOx limits for glass manufacturing furnaces include New York, Connecticut, and Maryland.

EPA focused its review on rules adopted by OTR states that contain specific RACT NOx limits for glass manufacturing furnaces. EPA reviewed Pennsylvania's RACT rule since it contains RACT NOx limits on a 30-day rolling average for various glass melting furnace types. Pennsylvania's NOx RACT rule requires owners or operators of a glass melting furnace to comply with the following emission limits: 4.0 pounds of NOx per ton of glass pulled for container and fiberglass furnaces, 7.0 pounds of NOx per ton of glass pulled for pressed/blown and flat glass furnaces, and 6.0 pounds of NOx per ton of glass pulled from all other glass melting furnaces.[67]

EPA also reviewed New Jersey's RACT rule since it contains a more stringent daily averaging period compared to Pennsylvania's RACT rule. New Jersey's NOx RACT rule requires each owner or operator of a glass manufacturing furnace to comply with the following emission limits: 4.0 pounds of NOx per ton of glass removed for container, pressed/blown, borosilicate, and fiberglass furnaces.[68] Under New Jersey's RACT rule, an owner or operator of a flat glass manufacturing furnace shall not emit more than 9.2 pounds of NOx per ton of glass removed. New Jersey's RACT rule also incorporates OTC model recommendations.[69]

Maryland's RACT rule requires owners or operators to optimize combustion by performing daily oxygen tests and maintain excess oxygen at 4.5% or less.[70] The San Joaquin

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[66] RACT NOx rules of the following OTR states CT, DC, DE, MD, ME, NH, NY, RI, VA, and VT do not establish specific NOx limits for glass manufacturing sources. These RACT regulations require owners or operators to submit RACT case-by-case analysis. See, Title 6 of New York's Codes, Rules, and Regulation (NYCRR) Part 220-2.3, *https://govt.westlaw.com/nycrr/Document/Iff7c8565a07611df8ec9d72f92627052?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)*, Section 22a-174-22e of CT's NOx RACT regulation, *https://eregulations.ct.gov/eRegsPortal/Browse/RCSA/Title_22aSubtitle_22a-174Section_22a-174-22e/*, and Title 26, Subtitle 11, Chapter 26.11.09 of MD's NOx RACT regulation, *http://www.dsd.state.md.us/comar/comarhtml/26/26.11.09.08.htm.*

[67] Title 25, Part I, Subpart C, Article III, Section 129.304 of PA's NOx RACT regulation provides emission rates for Glass Manufacturing Furnaces. *See https://casetext.com/regulation/pennsylvania-code-rules-and-regulations/title-25-environmental-protection/part-i-department-of-environmental-protection/subpart-c-protection-of-natural-resources/article-iii-air-resources/chapter-129-standards-for-sources/control-of-nox-emissions-from-glass-melting-furnaces/section-129304-emission-requirements*.

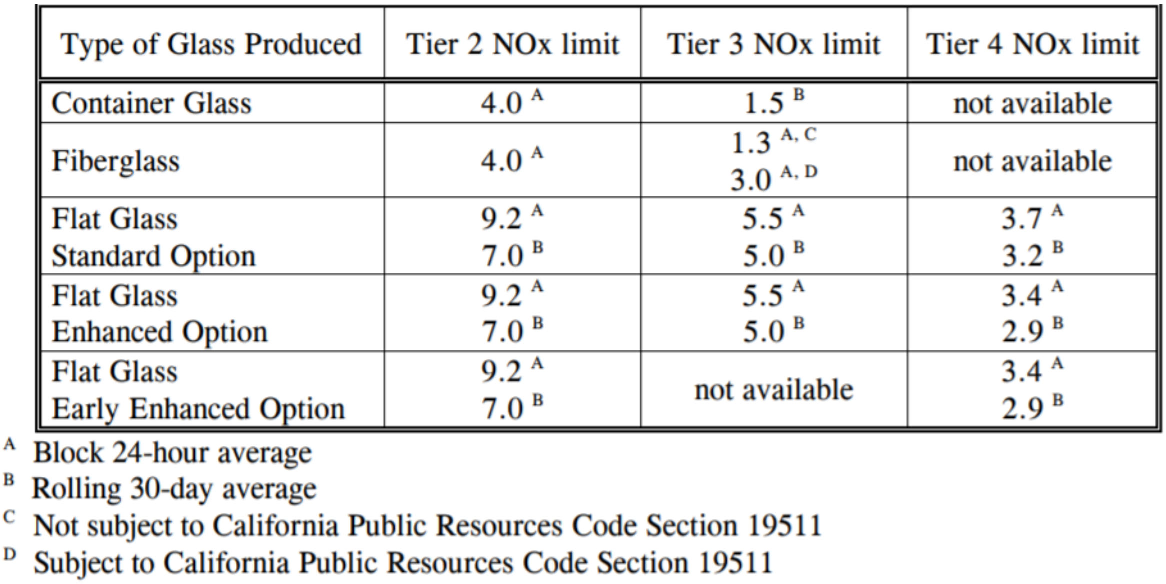
[68] Title 7, Chapter 27, Subchapter 19 of New Jersey's NOx RACT regulation provides NOx emission rates for Glass Manufacturing Furnaces. *See https://www.nj.gov/dep/aqm/currentrules/Sub19.pdf.*

[69] Id.

[70] Title 26, Subtitle 11, Chapter 26.11.09 of MD's NOx RACT regulation provides operation standards for Glass Manufacturing Furnaces. *See http://www.dsd.state.md.us/comar/comarhtml/26/26.11.09.08.htm.*

Valley air district in California has adopted RACT NOx emission limits that are based on both 30-day rolling and daily averages.[71]

The following table displays the San Joaquin Valley air district's emission limits for container glass, fiberglass, and flat glass melting furnaces.[72]



Type of Glass Produced	Tier 2 NOx limit	Tier 3 NOx limit	Tier 4 NOx limit
Container Glass	4.0 [A]	1.5 [B]	not available
Fiberglass	4.0 [A]	1.3 [A, C] 3.0 [A, D]	not available
Flat Glass Standard Option	9.2 [A] 7.0 [B]	5.5 [A] 5.0 [B]	3.7 [A] 3.2 [B]
Flat Glass Enhanced Option	9.2 [A] 7.0 [B]	5.5 [A] 5.0 [B]	3.4 [A] 2.9 [B]
Flat Glass Early Enhanced Option	9.2 [A] 7.0 [B]	not available	3.4 [A] 2.9 [B]

[A] Block 24-hour average
[B] Rolling 30-day average
[C] Not subject to California Public Resources Code Section 19511
[D] Subject to California Public Resources Code Section 19511

Emission Limits and Compliance Requirements in the Proposed Rule

In setting the emission limits for the Glass and Glass Product Manufacturing Sector, EPA reviewed RACT NOx rules, air permits, Alternative Control Techniques (ACT), and consent decrees. Based on EPA's review, EPA is proposing emission limits for this sector that are mostly expressed in terms of mass of pollutant emitted (pounds) per weight of glass removed from the furnace (tons), i.e., pounds of NOx emitted per ton of glass produced (lb/ton). Based on EPA's review, this form of NOx emission limit is effective, practicable, and convenient to record and report to an air agency.

In proposing a NOx emission limit for Container Glass Manufacturing Furnaces, EPA considered a range of emission limits from 1.0 to 5.0 lb/ton of glass produced. In particular, EPA notes that it has approved New Jersey's RACT rule limiting NOx emissions to 4.0 lb/ton of glass removed from the furnace. *See* 83 FR 50506 (October 9, 2018). This emission limit for Container Glass Furnaces in New Jersey's RACT rule is consistent with the NOx limit in Pennsylvania's RACT rule.[73]

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[71] *See* San Joaquin Valley Unified Air Pollution Control District, Rule 4354, "Glass Melting Furnaces" (amended May 19, 2011), available at *https://www.valleyair.org/rules/currntrules/R4354%20051911.pdf.*

[72] *See Id.*

[73] Title 25, Part I, Subpart C, Article III, Section 129.304 of PA's NOx regulation for glass manufacturing furnaces limit NOx emissions to 4.0 pounds of NOx per ton of glass pulled for container glass furnaces. *See https://casetext.com/regulation/pennsylvania-code-rules-and-regulations/title-25-environmental-protection/part-i-*

For Pressed/Blown and Fiberglass Manufacturing Furnaces, EPA considered a range of emission limits from 1.0 – 7.0 lb/ton of glass produced. EPA based the proposed emission limit of 4.0 lb/ton on EPA-approved New Jersey and Pennsylvania RACT rules for glass melting furnaces. EPA also observed that the 4.0 lb/ton limit was consistent for these types of glass manufacturing furnaces with states located in the OTR. *See* 76 FR 52283 (August 22, 2011).

For Flat Glass Manufacturing Furnaces, EPA considered a range of 5.0 – 9.2 lb/ton of glass produced. EPA based the proposed emission limit of 9.2 lb/ton on the NOx limits in the New Jersey and San Joaquin Valley air district's federally approved RACT rules.

In determining the averaging time for the limits, EPA reviewed the NSPS for glass manufacturing plants codified in 40 CFR Part 60 Subpart CC. EPA also referred to the various state RACT NOx rules that contain specific NOx emission limits for the glass manufacturing industry. We note that the NSPS for glass manufacturing furnaces establishes standards only for particulate matter and does not establish standards or averaging times for NOx. In order to determine an appropriate averaging time for the proposed NOx emission limits, EPA focused its review on the various RACT NOx rules from states located in the OTR. The OTR states have adopted emission limits with varying averaging times. Based on EPA's review, the OTR states varied between a 30-day rolling average or a more stringent daily average.[74] EPA also reviewed RACT NOx regulations for the glass manufacturing sector outside the OTR and observed that 30-day rolling averages and daily averages varied throughout the states.[75] In the preamble to this proposed rule, EPA is proposing to require owners and operators of glass manufacturing furnaces to comply with the proposed NOx emission limit on a 30-day rolling average time frame. EPA believes that this averaging time frame is consistent with other statewide RACT NOx regulations for this particular sector. A 30-day operating day rolling average strikes a balance between short term (hourly or daily) and long term (annual) averaging periods, while being flexible and responsive to fluctuations in operation and production.

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department-of-environmental-protection/subpart-c-protection-of-natural-resources/article-iii-air-resources/chapter-129-standards-for-sources/control-of-nox-emissions-from-glass-melting-furnaces/section-129304-emission-requirements.

[74] Pennsylvania's RACT NOx emission limits are based on 30-day rolling average. *See* Title 25, Part I, Subpart C, Article III, Section 129.304, *see https://casetext.com/regulation/pennsylvania-code-rules-and-regulations/title-25-environmental-protection/part-i-department-of-environmental-protection/subpart-c-protection-of-natural-resources/article-iii-air-resources/chapter-129-standards-for-sources/control-of-nox-emissions-from-glass-melting-furnaces/section-129304-emission-requirements.* New Jersey's and Massachusetts' rules contain more stringent daily averages. Title 7, Chapter 27, Subchapter 19 of New Jersey's NOx RACT regulation provides NOx emission rates for Glass Manufacturing Furnaces. *See https://www.nj.gov/dep/aqm/currentrules/Sub19.pdf.* 310 CMR Section 7:19 of Massachusetts regulations provides RACT NOx emission limits for Glass Manufacturing Furnaces. *See https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download*. Title 26, Subtitle 11, Chapter 26.11.09 of Maryland's NOx RACT regulation provides operation standards for Glass Manufacturing Furnaces. *See http://www.dsd.state.md.us/comar/comarhtml/26/26.11.09.08.htm.*

[75] The San Joaquin Valley air district's RACT NOx emission limits are based on both 30-day rolling and daily averages. *See* San Joaquin Valley Unified Air Pollution Control District, Rule 4354, "Glass Melting Furnaces" (amended May 19, 2011), available at *https://www.valleyair.org/rules/currntrules/R4354%20051911.pdf.* Wisconsin's NOx emission limits are based on a 30-day rolling average. See Wisconsin's Administrative Code NR Section 428.22 (November 29, 2021), available at *https://casetext.com/regulation/wisconsin-administrative-code/agency-department-of-natural-resources/environmental-protection-air-pollution-control/chapter-nr-428-control-of-nitrogen-compound-emissions/subchapter-iv-nox-reasonably-available-control-technology-requirements/section-nr-42822-emission-limitation-requirements.*

Performance Test and Monitoring

EPA is proposing to require that performance tests be conducted on a semiannual basis in accordance with the applicable reference Test Methods of 40 CFR 60, Appendix A, or other methods and procedures approved by EPA through notice-and-comment rulemaking.

EPA is specifically proposing to require each owner or operator of an affected unit to install, calibrate, maintain, and operate a CEMS for the measurement of NOx emissions discharged into the atmosphere from the affected unit. EPA is soliciting comments on alternative monitoring systems and methods that are equivalent to CEMS to demonstrate compliance with the emission limits.

6 Boilers from Basic Chemical Manufacturing, Petroleum and Coal Products Manufacturing, and Pulp, Paper, and Paperboard Mills

A. Applicability and form of proposed emissions limits for industrial boilers.

EPA proposes to establish regulatory requirements for boilers that have a design capacity of 100 mmBtu/hr or greater within the Basic Chemical Manufacturing, Petroleum and Coal Products Manufacturing, and Pulp, Paper, and Paperboard Mills industries. The rationale for this proposal is consistent with EPA's findings at Step 3 with respect to Tier 2 non-EGU industries in that it applies to certain boilers located at facilities identified as a Tier 2 industry within the Non-EGU Screening Assessment memorandum, which can be found within the docket for the proposed rule. As described within the Non-EGU Screening Assessment memorandum, EPA reviewed the projected 2026 emissions data to identify large boilers within the Tier 2 industries, defined as boilers projected to emit more than 100 tons per year in 2026. Boilers meeting this threshold were found in three of the five Tier 2 industries, as identified in Table 1 below.

Table 1: Tier 2 Industries with Large Boilers and Associated NAICS Codes

Industry	NAICS Code
Basic Chemical Manufacturing	3251xx
Petroleum and Coal Products Manufacturing	3241xx
Pulp, Paper, and Paperboard Mills	3221xx

EPA is not currently aware of boilers meeting this size classification within the other Tier 2 or Tier 1 industries but proposes to require that any such boilers would also be subject to the requirements of the FIP. Based on a review of the potential emissions from industrial boilers of various fuel types as described in this section, we believe that use of a boiler design capacity of 100 mmBtu/hr reasonably approximates the selection of 100 tpy used within the Non-EGU Screening Assessment memorandum. Therefore, EPA proposes to establish NOx emissions limits for all new and existing boilers found within any of the 23 covered states that are within a Tier 1 or Tier 2 industry and have a design capacity of 100 mmBTU/hr or greater. EPA solicits comment on alternative applicability thresholds, such as one based strictly on potential to emit.

EPA reviewed a number of state RACT rules to determine the typical form of emission limits within them. Based on this review, EPA found that NOx limits for industrial boilers most often take the form of design capacity expressed as mass of NOx emitted per million BTUs combusted per hour. EPA's proposed NOx emissions limits for this source category take the same form.

Specifically, EPA is proposing to establish an applicability threshold based on a design capacity of 100 mmBtu/hr or greater. NOx emissions from boilers rated at 100 mmBtu/hr or greater can be significant, particularly if they do not operate NOx control equipment. Based on our review of the potential emissions from industrial boilers of various fuel types we conclude that use of a boiler design capacity of 100 mmBtu/hr reasonably approximates the selection of 100 tons/year used within the Non-EGU Screening Assessment memorandum. An evaluation of potential NOx emissions from various fossil-fueled industrial boilers with a design capacity of 100 mmBtu/hr is provided below.

1. Potential emissions from coal-fired industrial boilers

The potential emissions from a coal-fired industrial boiler with a design capacity of 100 mmBtu/hr was estimated using an average NOx emission factor from EPA's emission factor reference document, AP-42[76], along with an approximate heating value for coal from Appendix A of AP-42. The emission factor used was derived by calculating the average of 13 "A" rated NOx emission factors from AP-42's Table 1.1-3 – Emission Factors for SOx, NOx, and CO from Bituminous and Subbituminous Coal Combustion. The average of the 13 values was 14.1 lbs NOx per ton of coal burned. The heating value from Appendix A for bituminous coal is 13,000 BTUs per pound, which equates to 26 million BTUs per ton of coal. The following calculation provides the maximum potential emissions from an industrial boiler with these parameters:

*(14.1 lbs NOx/ton coal) * (1 ton coal/26 mmBtu) * (100 mmBtu/hr) * (8,760 hr/yr) *(1 ton/2000 lbs) = 237.5 tons NOx/year.*

The above represents the maximum potential emissions from a coal-fired boiler emitting at the rate shown in the equation; boilers operating less than 8,760 hours per year would emit proportionally less than the maximum amount illustrated in the above equation.

2. Potential emissions from oil-fired industrial boilers.

The potential emissions from a residual and a distillate oil-fired industrial boiler with a design capacity of 100 mmBtu/hr was estimated in a manner similar to the approach described above for a coal-fired industrial boiler. For a residual oil-fired industrial boiler, a NOx emission factor of 47 lbs NOx per 1,000 gallons of oil burned was taken from Table 1.3-1, Criteria Pollutant Emission Factors for Fuel Oil Combustion, of section 1.3, Fuel Oil Consumption, of AP-42, and a heating value of 150,000 BTUs per gallon for residual oil as reported in Appendix A to AP-42 was used. The heating value equates to 150 million BTUs per 1,000 gallons used. The following calculation provides the maximum potential emissions from an industrial boiler with these parameters:

*(47 lbs NOx/1,000 gallons) * (1,000 gallons/150 mmBtu) * (100 mmBtu/hr) * (8,760 hr/yr) *(1 ton/2000 lbs) = 137.2 tons NOx/year.*

For a distillate oil-fired boiler, an emission factor of 24 lbs NOx/1,000 gallons from Table 1.3-1 was used in conjunction with a heat rate of 140,000 BTUs per gallon from Appendix A. Substituting these values into the above equation yields a result of 75.1 tons per year. Although this result is below 100 tons per year, the emission factor used, which was the only one available for industrial boilers of this size and fuel type within AP-42 is rated "D", meaning there is likely to be a fairly wide range in emission rates from individual boilers of this type.

The above analysis represents the maximum potential emissions from a residual and a distillate-fired industrial boiler emitting at the rates shown in the equations above; boilers

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[76] Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources; U.S. EPA, Office of Air Quality Planning and Standards; available at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

operating less than 8,760 hours per year would emit proportionally less than the maximum amounts illustrated in the above equations.

3. Potential emissions from a natural gas-fired industrial boiler.

The potential emissions from a natural gas-fired industrial boiler with a design capacity of 100 mmBtu/hr was estimated in a manner similar to the approach described above for coal and oil-fired industrial boilers. For a natural gas-fired industrial boiler, a NOx emission factor of 235 lbs NOx per million standard cubic feet (SCF) used was obtained from Table 1.4-1, Emission Factors for Nitrogen Oxides (NOx) and Carbon Monoxide (CO) from Natural Gas Combustion, of section 1.4, Natural Gas Consumption, of AP-42. The emission factor represents the average of the emission factors for a pre and a post-NSPS natural gas-fired industrial boiler. A heating value of 1,050 BTUs per SCF as reported in Appendix A to AP-42 was used in the calculation. The heating value equates to 1,050 mmBtu per million SCF. The following calculation provides the maximum potential emissions from an industrial boiler with these parameters:

*(235 lbs NOx/mm SCF) * (1 mm SCF/1,050 mmBtu) * (100 mmBtu/hr) * (8,760 hr/yr) *(1 ton/2000 lbs) = 98 tons NOx/year.*

The above analysis represents the maximum potential emissions from a residual and a distillate-fired industrial boiler emitting at the rates shown in the equations above; boilers operating less than 8,760 hours per year would emit proportionally less than the maximum amounts illustrated in the above equations.

B. Proposed Emissions Limitations and Rationale

A review was performed of NOx emissions limits for industrial boilers with design capacities of 100 mmBtu/hr or greater that have been adopted by states and incorporated into their SIPs. Based on that review, the following NOx emissions limits for coal, oil, and gas fired industrial boilers appear to be reasonable, achievable limits for industrial boilers:

Table 2: Recommended NO_X Emissions Limits for Industrial Boilers > 100 mmBtu/hr

Unit type	Emissions limit (lbs NOx/mmBtu)	Additional Information
Coal	0.20	Limits reviewed ranged from 0.08 to 1.0. Proposed limit will likely require a combination of combustion controls or post-combustion controls.
Residual oil	0.20	Limits reviewed ranged from 0.15 to 0.50. Proposed limit will likely require combustion controls.
Distillate oil	0.12	Limits reviewed ranged from 0.10 to 0.43. Proposed limit will likely require combustion controls.
Natural gas	0.08	Limits reviewed ranged from 0.06 to 0.25. Proposed limit will likely require a combination of combustion controls or post-combustion controls.

EPA's Menu of Control Measures (MCM) document contains numerous examples of NOx control equipment that has been demonstrated to effectively reduce emissions from industrial boilers. Table 7 below provides information pertaining to industrial boilers from the MCM, indicating that 9 different control technologies or combinations of technologies have been shown to reduce NOx emissions from industrial boilers with control efficiencies ranging from 35 to 90 percent. This information from the MCM can also be found in the Control Measures Database (CMDB), a major input to the Control Strategy Tool (CoST), which EPA used in the NOx control strategy analysis included in the Non-EGU Screening Assessment memorandum.[77]

Additional information on EPA's analysis of state-adopted emission limits for industrial boilers with design capacities of 100 mmBtu/hr or greater fueled by coal, oil, or natural gas, and the control technologies available to reduce NOx emissions from this equipment is provided below.

1. Coal-fired industrial boilers

For coal-fired industrial boilers subject to the requirements of the proposed FIP, EPA is proposing to establish an emission limit of 0.20 lbs/MMBtu on a 30-day rolling basis. Various forms of combustion and post-combustion NOx control technology exist that should enable most existing facilities to be retrofit with equipment that will enable them to meet this emissions limit. Additionally, many states containing ozone nonattainment areas or located within the Ozone Transport Region (OTR) have already adopted emission limits similar to the recommended emission limit. Furthermore, some coal-fired industrial boilers may have installed combustion or post-combustion control equipment to meet the emission limits contained within EPA's NSPS

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[77] EPA, Control Measures Database (CMDB) for Stationary Sources, available at https://www.epa.gov/system/files/other-files/2021-09/cmdb_2021-09-02_0.zip (URL dated January 6, 2022).

located at 40 CFR 60 Subpart Db, which requires that coal-fired industrial boilers meet a NOx emissions limit of between 0.5 and 0.8 lbs/MMBtu depending on unit type.[78]

There are two main types of NOx control technology that can be retrofit to most existing industrial boilers, or incorporated into the design of new boilers, to meet the proposed emissions limit. These two control types are combustion controls and post-combustion controls, and in some instances both types are used together. As noted within EPA's "Alternative Control Techniques Document – NOx Emissions from Industrial / Commercial / Institutional (ICI) Boilers" (hereafter "ICI Boiler ACT"),[79] the type of NOx control available for use on a particular unit depends primarily on the type of boiler, fuel type, and fuel-firing configuration. We note that although the ICI Boiler ACT also addresses emissions from commercial and institutional boilers, we are not proposing emissions limits for those types of boilers; rather, we are only proposing limits for certain types of industrial boilers. For example, Table 2-3 of the ICI Boiler ACT indicates which types of combustion and post-combustion NOx controls are suitable to various types of coal-fired ICI boilers. We note that one type of combustion control, staged combustion air, and one type of post-combustion control, SNCR, are indicated as being compatible with all coal-fired unit types. Additional resources are available that document the availability of NOx control equipment for industrial boilers, including a document prepared by the Northeast States for Coordinated Air Use Management entitled, "Applicability and Feasibility of NOx, SO2, and PM Emission Control Technologies for Industrial, Commercial, and Institutional Boilers" (November 2008, revised January 2009); the "EPA Air Pollution Control Cost Manual," Section 4, Chapter 1: Selective Noncatalytic Reduction, April, 2019 and Chapter 2, Selective Catalytic Reduction, June 2019; and a document issued by the Institute of Clean Air Companies entitled, "Typical Installation Timelines for NOx Emissions Control Technologies on Industrial Sources," December, 2006.

Table 3 provides examples of NOx emission limits for coal-fired ICI boilers rated at 100 mmBTU/hr or greater that have been adopted by various states.

Table 3 – NOx emission limits, averaging times, and state citations for coal fired ICI boilers

State	Emission limit (lbs/mmBTU)	Averaging time	State rule citation and website
CT	0.12[80] ozone season; 0.15 non-ozone season	Daily block average for units with CEMS, for other units, as developed during stack testing. For non-ozone season, rate is avg. for non-ozone season.	Section 22a-174-22e of the Regulations of Connecticut State Agencies, at paragraph (d)(2)(C): https://eregulations.ct.gov/eRegsPortal/Browse/RCSA/Title_22aSubtitle_22a-174Section_22a-174-22e/

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[78] 40 CFR 60.44b.

[79] EPA, Alternative Control Techniques Document – NOx Emissions from Industrial / Commercial / Institutional (ICI) Boilers, EPA-453/R-94-022 [DATE].

[80] Beginning in 2023.

MA	0.12	One-hour, unless equipped with CEMS, then daily.	Regulation 310 of the Code of Massachusetts Regulations (CMR), 7.00, Air Pollution Control, Section 7.19, RACT for Sources of NOx, at paragraph (4)(b): https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download
DE	0.38	24 hour rolling basis.	Title 7, Natural Resources and Environmental Control, Section 1112, Control of Nitrogen Oxide Emissions, at Table 3-1: https://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml
NY	0.08 – 0.20	CEMS or 1-hour average.	Title 6, Dept. of Environmental Conservation; Chapter III. Air Resources; Subchapter A. Prevention and Control of Air Contamination and Air Pollution; Part 227. Stationary Combustion Installations; Subpart 227-2. RACT for Major Sources of NOx. NY NOx RACT Regulation

2. Oil-fired industrial boilers

Most oil-fired boilers are fueled by either residual (heavy) oil or distillate (light) oil. Based on our review of available information as described below, the proposed NOx emission limit for residual oil-fired boilers is 0.20 lbs/mmBtu, and the proposed emission limit for distillate oil-fired boilers is 0.12 lbs/mmBtu, with both limits based on a rolling, 30-day average basis. As with coal-fired industrial boilers, a number of combustion and post-combustion NOx control technology exist that should enable most facilities to meet these emission limits, and numerous examples exist of states that have already adopted emission limits similar to EPA's proposed emissions limits. Table 2-3 of the ICI Boiler ACT indicates that two types of NOx combustion control, low-NOx burners and flue gas recirculation, are commonly found on oil-fueled industrial boilers, and that SNCR, a post-combustion control technology, is suitable to most oil-fueled industrial boilers other than those of the packaged firetube design. Some oil-fired industrial boilers may have already installed combustion or post-combustion control equipment to meet the emission limits contained within EPA's NSPS located at 40 CFR 60 Subpart Db, which requires that distillate oil-fired units meet a NOx emission limit of between 0.1 to 0.2 lbs/MMBtu depending on heat release rate, and residual oil-fired units meet a NOx emission limit of between 0.3 to 0.4 lbs/MMBtu also depending on heat release rate.[81] The additional resources noted in the paragraph above discussing coal-fired industrial boilers also contain useful information regarding effective NOx control equipment for residual and distillate fueled industrial boilers.

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[81] 40 CFR 60.44b.

Table 4 provides examples of NOx emission limits for oil-fired ICI boilers rated at 100 mmBTU/hr or greater that have been adopted by various states.

Table 4 – NOx emission limits, averaging times, and state citations for oil-fired ICI boilers rated at 100 mmBTU/hr or greater

State	**Emission limit** (lbs/mmBTU)	**Averaging time**	**State rule citation**
CT[82]	Residual oil: 0.20 Other oil: 0.15	Daily block average for units with CEMS, for other units, as developed during stack testing.	Section 22a-174-22e of the Regulations of Connecticut State Agencies, at paragraph (d)(3)(C): https://eregulations.ct.gov/eRegsPortal/Browse/RCSA/Title_22aSubtitle_22a-174Section_22a-174-22e/
MA	0.15	One-hour, unless equipped with CEMS, then daily.	310 CMR 7.19, at paragraph (4)(b): https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download
DE	0.25 all boilers except cyclone boilers; cyclone boilers, 0.43	24 hour rolling basis.	Title 7, Natural Resources and Environmental Control, Section 1112, Control of Nitrogen Oxide Emissions, at Table 3-1: https://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml
NY	0.15 – 0.20	CEMS or 1-hour average.	Same citation as shown in Table 3.
NJ	Distillate – 0.10 Other liq. – 0.20	If CEMs, daily avg., otherwise, periodic stack test	Title 7, New Jersey Administrative Code, Chapter 27, Subchapter 19, Control and Prohibition of Air Pollution from Oxides of Nitrogen, available at: https://www.nj.gov/dep/aqm/currentrules/Sub19.pdf

3. Gas-fired industrial boilers

The proposed NOx emission limit for gas-fired boilers is 0.08 lbs/mmBtu on a 30-day rolling average basis. As with fossil-fuel-fired boilers mentioned above, numerous combustion and post-combustion NOx control technology exist that should enable most facilities to meet these emission limits, and many examples exist of states that have already adopted emission limits similar to EPA's proposed emissions limits. Table 2-3 of the ICI Boiler ACT indicates the same control technologies suitable to application to oil-fired boilers are also likely to be effective

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[82] Rates shown for CT are applicable during the ozone season.

at controlling NOx emissions from gas-fired industrial boilers. Some gas-fired industrial boilers may have already installed combustion or post-combustion control equipment to meet the emission limits contained within EPA's NSPS located at 40 CFR 60 Subpart Db, which requires that gas-fired units meet a NOx emission limit of between 0.1 to 0.2 lbs/MMBtu depending on heat release rate. The additional resources noted in the discussion of coal-fired industrial boilers also contain useful information regarding effective NOx control equipment for gas-fired industrial boilers.

Table 5 provides examples of NOx emission limits for gas-fired ICI boilers rated at 100 mmBTU/hr or greater that have been adopted by various states.

Table 5 – NOx emission limits, averaging times, and state citations for gas-fired ICI boilers with design capacity of 100 mmBTU/hr or greater:

State	Emission limit (lbs/mmBTU)	Averaging time	State rule citation
CT[83]	0.10	Daily block average for units with CEMS, for other units, as developed during stack testing.	Section 22a-174-22e of the Regulations of Connecticut State Agencies, at paragraph (d)(3)(C): https://eregulations.ct.gov/eRegsPortal/Browse/RCSA/Title_22aSubtitle_22a-174Section_22a-174-22e/
MA	0.06	One-hour, unless equipped with CEMS, then daily.	310 CMR 7.19, at paragraph (4)(b): https://www.mass.gov/doc/310-cmr-700-air-pollution-control-regulations/download
DE	0.20	24 hour rolling basis.	Title 7, Natural Resources and Environmental Control, Section 1112, Control of Nitrogen Oxide Emissions, at Table 3-1: https://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml
NY	0.08	CEMS or 1-hour average.	Same as citation shown in Table 3.
NJ	0.10	If CEMS, daily average; otherwise, periodic stack test.	Title 7, New Jersey Administrative Code, Chapter 27, Subchapter 19, Control and Prohibition of Air Pollution from Oxides of Nitrogen, available at: https://www.nj.gov/dep/aqm/currentrules/Sub19.pdf

4. Industrial boilers using other fuels

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[83] Rates shown for CT are applicable during the ozone season.

Based on our review of available data, our expectation is that there will be less than 100 industrial boilers subject to these requirements, the majority of which will be powered by coal, oil, or natural gas. However, there may be industrial boilers rated at 100 mmBtu/hr or greater located at one of the indicated industries powered by other fuels such as wood or industrial process gas. EPA solicits comment on whether EPA should establish emission limits for such other types of fuels should as part of the final FIP.

D. What types of NOx controls are available to meet the proposed emission limits, and what are the approximate costs per ton of NOx removed?

EPA believes that the NOx control technologies for industrial boilers mentioned above can be retrofit to existing boilers, or incorporated into the design of new boilers, in a cost-effective manner. Information developed for a prior air pollution transport rule referred to as the Cross State Air Pollution Rule (CSAPR) include the following document: “Final Technical Support Document (TSD) for the Cross State Air Pollution Rule for the 2008 Ozone NAAQS; Docket ID No. EPA-HQ-OAR-2015-0500; Assessment of Non-EGU NOx Emission Controls, Cost of Controls, and Time for Compliance Final TSD” (hereafter “CSAPR Non-EGU TSD”). The analysis contained within that report was obtained primarily from the Control Strategy Tool (CoST), which is software that produces emission reduction and cost estimates for various non-EGU control strategy options. A summary of the results from the CoST model are provided in Table 3 of the CSAPR Non-EGU TSD, and a summary of the information applicable to industrial boilers is provided in Table 6 below.

Table 6: CoST Results from the CSAPR Non-EGU TSD for Industrial Boilers

Non-EGU Source Group	**Control Technology Recommended by CoST**	**Current Estimate of NOx $/ton, CoST (2011$)**
Boilers and Process Heaters; External Combustion Boilers	SCR	$2,235
Coal Boilers	SNCR	$2,413
ICI Boilers – Residual Oil	LNB & SNCR	$2,850
ICI Boilers	Low NOx Burners & SCR	$3,456

The information above indicates that there are cost effective NOx control options that can be used on industrial boilers.

E. Compliance Assurance Requirements

Boilers subject to the requirements of this section of the proposed FIP should demonstrate compliance in a manner similar to the emissions monitoring requirements found within the NSPS for industrial, commercial, and institutional (ICI) boilers at 40 CFR Part 60 Subpart D, at section 60.46b. Those requirements include, among other provisions, the performance of an initial compliance test and installation of a CEMS. The proposed FIP includes a CEMS opt out requirement similar to that within 40 CFR Part 60 Subpart D, Standards of Performance for Fossil-Fuel-Fired Steam Generators, for sources whose initial compliance test indicates the unit emits at 70% or less of the applicable standard.

EPA is proposing to require that the initial compliance test be conducted no later than 90 days after the installation of control applied to meet the proposed emission standards, and performed as described under 40 CFR Part 60.8 using the continuous system for monitoring NOx specified by EPA Test Method 7E – Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure), as described at 40 CFR Part 60, Appendix A-4. EPA is also proposing to require that, in lieu of the timing of the compliance test described under 40 CFR § 60.8(a), the test shall be conducted within 90 days from the installation of the pollution control equipment used to comply with the NOx emission limits of this section.

Table 7 – Excerpt from Menu of Control Measures Applicable to Industrial Boilers

Source Category	**Emission Reduction Measure**	**Control Efficiency (%)**	**Description/Notes/Caveats**	**References**
Industrial/ Commercial/ Institutional Boilers - Coal	Selective Catalytic Reduction	80	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal ICI boilers with NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
Industrial/ Commercial/ Institutional Boilers - Coal	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, Pechan 2006
Industrial/ Commercial/ Institutional Boilers - Coal or Petroleum Coke	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010

			amount of oxygen available in another. This control is applicable to coal/wall fired ICI boilers and Petroleum coke fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	
Industrial/ Commercial/ Institutional Boilers - Coal or Petroleum Coke - Wall Fired	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to wall fired (coal) IC boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal-fired and petroleum coke-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
Industrial/ Commercial/ Institutional Boilers - Coal/ Bituminous	Low NOx Burner and Over Fire Air	51	This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between	EPA 2003b, Pechan 2006

			fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to bituminous coal Industrial/Commercial/Institutional (ICI) boilers.	
Industrial/ Commercial/ Institutional Boilers - Coal/ Subbituminous	Low NOx Burner	51	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to subbituminous coal industrial/commercial/institutional boilers. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2003b, Pechan 2006, OTC/LADCO 2010
Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Coal Reburn	50	This control reduces NOx emissions through coal reburn. This control is applicable to coal/cyclone ICI boilers.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 1994g, Cadmus 1995
Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Natural Gas Reburn	55	Natural gas reburning (NGR) involves add-on controls to reduce NOx emissions. NGR is a combustion control technology in which part of the main fuel heat input is diverted to locations above the main burners, called the reburn zone. As flue gas passes through the reburn zone, a portion of the NOx formed in the main combustion zone is reduced by hydrocarbon radicals and converted to	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g

			molecular nitrogen (N2). This control applies to coal/cyclone ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	
Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal/cyclone ICI boilers with nameplate capacity greater than 25 MW (250 mmBTU/hr).	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, EPA 2010a
Industrial/ Commercial/ Institutional Boilers - Coal/ Cyclone	Selective Non-Catalytic Reduction	35	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal/cyclone IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
Industrial/ Commercial/ Institutional Boilers - Coal/ Fluidized Bed Combustion	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to fluidized bed combustion coal ICI boilers.	EPA 2007b
Industrial/ Commercial/ Institutional Boilers - Coal/ Fluidized Bed Combustion	Selective Non-Catalytic Reduction - Urea	75	This control is the reduction of NOx emission through urea based selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g

			oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal-fired/fluidized bed combustion IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	
Industrial/ Commercial/ Institutional Boilers - Coal/ Stoker	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal/stoker IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2007b
Industrial/ Commercial/ Institutional Boilers - Coal/ Stoker	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls to coal/stoker IC boilers. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to coal/stoker IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
Industrial/ Commercial/ Institutional Boilers - Coal/ Subbituminous	Low NOx Burner and Over Fire Air	65	This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to subbituminous coal Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006

Industrial/ Commercial/ Institutional Boilers - Coal/ Wall	Selective Catalytic Reduction	90	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to coal/wall IC boilers with nameplate capacity greater than 25 MW.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, EPA 2010a
Industrial/ Commercial/ Institutional Boilers - Distillate Oil	Selective Catalytic Reduction	80	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to distillate oil-fired ICI boilers with nameplate capacity greater than 25 MW.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 2007d, Sorrels 2007, EPA 2010a
Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to Oil and LPG ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010

			Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	
Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Low NOx Burner and Flue Gas Recirculation	60	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to distillate oil-fired ICI boilers and LPG-fired ICI Boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
Industrial/ Commercial/ Institutional Boilers - Distillate Oil or LPG	Selective Non-Catalytic Reduction	50	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to distillate oil and LPG-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g
Industrial/ Commercial/ Institutional Boilers - Gas	Low NOx Burner and Flue Gas Recirculation + Over Fire Air	80	This control is the use of low NOx burner (LNB) technology, flue gas recirculation (FGR), and over fire air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to gas Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, EPA 1998e
Industrial/ Commercial/ Institutional Boilers - Gas	Low NOx Burner and Over Fire Air	60	This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of	EPA 2003b, Pechan 2006

			NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to gas Industrial/Commercial/Institutional (ICI) boilers.	
Industrial/ Commercial/ Institutional Boilers - Gas	Selective Catalytic Reduction	80	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to gas-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
Industrial/ Commercial/ Institutional Boilers - Gas	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, Pechan 2006
Industrial/ Commercial/ Institutional Boilers - Natural Gas	Selective Non-Catalytic Reduction	50	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to natural gas fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b
Industrial/ Commercial/	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce	EPA 2006b, Pechan 2001,

Institutional Boilers - Natural Gas or Process Gas			NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas and process gas fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Low NOx Burner and Flue Gas Recirculation	60	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to natural gas-fired and process gas-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Oxygen Trim and Water Injection	65	This control is the use of Oxygen Trim and Water Injection to reduce NOx emissions. Water is injected into the gas turbine, reducing the temperatures in the NOx-forming regions. The water can be injected into the fuel, the combustion air or directly into the combustion chamber. This control applies to natural gas-fired and process gas-fired ICI boilers with uncontrolled	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, ERG 2000, EPA 1994g

			NOx emissions greater than 10 tons per year.	
Industrial/ Commercial/ Institutional Boilers - Natural Gas or Process Gas	Selective Catalytic Reduction	80	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to natural gas fired and process gas-fired ICI boilers nameplate capacity greater than 25 MW.	EPA 2006b, EPA 1998e, EPA 2002a, EPA 2007d, Sorrels 2007, EPA 2010a
Industrial/ Commercial/ Institutional Boilers - Oil	Low NOx Burner and Over Fire Air	50	This control is the use of low NOx burner (LNB) technology and Over Fire Air (OFA) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control applies to oil Industrial/Commercial/Institutional (ICI) boilers.	EPA 2003b, Pechan 2006
Industrial/ Commercial/ Institutional Boilers - Oil	Selective Catalytic Reduction	80	This control is the selective catalytic reduction of NOx through add-on controls. SCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). The SCR utilizes a catalyst to increase the NOx removal efficiency, which allows the process to occur at lower temperatures. This control applies to oil-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2003b, EPA 1998e
Industrial/ Commercial/ Institutional Boilers - Oil	Selective Non-Catalytic Reduction	40	This control is the reduction of NOx emission through selective non-catalytic reduction add-on controls. SNCR controls are post-combustion	EPA 2003b, Pechan 2006

			control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to oil IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	
Industrial/ Commercial/ Institutional Boilers - Residual Oil or Liquid Waste	Low NOx Burner	50	This control is the use of low NOx burner (LNB) technology to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired ICI boilers and liquid waste fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year. Cost estimates are from the OTC / LADCO Workgroup (OTC / LADCO Control Cost Subgroup), for a single burner (for a 66% capacity factor at 8760 hours/year), and are based on a methodology similar to EPA's methodology provided in EPA document "Alternative Control Techniques Document – NOx Emissions from Industrial/Commercial/Institutional (ICI) Boilers".	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1994g, OTC/LADCO 2010
Industrial/ Commercial/ Institutional Boilers - Residual Oil or Liquid Waste	Low NOx Burner and Flue Gas Recirculation	60	This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another. This control is applicable to residual oil-fired and liquid waste-fired ICI boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 2006b, Pechan 2001, EPA 1998e, EPA 2002a, EPA 1993c
Industrial/ Commercial/	Selective Non-	50	This control is the reduction of NOx emission through selective non-	EPA 2006b, Pechan 2001,

Institutional Boilers - Residual Oil or Liquid Waste	Catalytic Reduction		catalytic reduction add-on controls. SNCR controls are post-combustion control technologies based on the chemical reduction of nitrogen oxides (NOx) into molecular nitrogen (N2) and water vapor (H2O). This control applies to residual oil and liquid waste-fired IC boilers with uncontrolled NOx emissions greater than 10 tons per year.	EPA 1998e, EPA 2002a, EPA 1994g

The information in the table above is an excerpt from EPA's Menu of Control Measures.

7 Municipal Waste Combustors

MWCs emit substantial amounts of NOx, and some states have required emission limits for these facilities that are more stringent than the federal requirements contained within EPA's NSPS for this industry. These more stringent limits, if implemented within the final FIP, would create an additional means of reducing NOx emissions across many of the states affected by the FIP. EPA has received comments in past transport rulemakings that emission reductions should be sought from MWCs, as noted within the RCU proposed rule (85 FR 68993). While EPA is not currently proposing any emission limits for MWCs, EPA is soliciting comment on whether the final FIP should establish NOx emissions limits for new and existing MWCs located in the states affected by the proposed FIP.

Summary of MWC Industry and Emissions

MWCs burn garbage and other non-hazardous solid material using a variety of combustion techniques. Section 2.1, Refuse Combustion, of EPA emission factor reference document AP-42 contains a description of the seven different combustion process technologies most commonly used in the industry. These seven combustion processes are as follows: Mass burn waterwall, mass burn rotary waterwall, mass burn refractory wall, refuse-derived fuel-fired, fluidized bed, modular starved air, and modular excess air. Section 2.1 of AP-42 contains detailed process descriptions of each of these MWC processes. During the combustion process, a number of pollutants are produced, including NOx, which forms through oxidation of nitrogen in the waste and from fixation of nitrogen in the air used to burn the waste. NOx emissions from MWCs are typically released through tall stacks which enables the emissions to be transported long distances.

Most MWCs are co-generation facilities in that they recover heat from the combustion process to power a turbine to produce electricity. According to a 2018 report from the Energy Recovery Council,[84] 72 of the 75 operating MWC facilities in the U.S. produce electricity from heat captured from the combustion process. The electrical output of MWCs is relatively small compared to the EGUs that will be regulated per the requirements of the proposed FIP, with most MWCs having an electrical output capacity of less than 25 MW. Appendix 1 of this TSD contains a Microsoft Excel spreadsheet listing all of the MWC units in the U.S. and includes each unit's electrical output capacity as reflected in EPA's most recent version of the NEEDS database (June 2021). All MWCs in the states included in the proposed FIP have an electrical output capacity of less than 25 MW. The average electrical output capacity is 12.8 MW.

NOx emissions from MWCs located in the transport states identified in this proposal are substantial. According to EPA's National Emission Inventory (NEI) database, in 2017[85] 20,344 tons of NOx were emitted from MWCs in the ten transport states containing them. Table 8 contains a list of MWC facilities located within a transport state along with their NOx emissions as reported to the 2017 NEI. Data reported to the 2017 NEI indicates that NOx emissions from

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[84] "2018 Directory of Waste to Energy Facilities"; Energy Recovery Council.

[85] Emissions data for Indiana's Covanta facility located in Indianapolis was taken from the 2019 NEI because emissions for that facility were not reported to EPA by the state for that year. Data for all other facilities was taken from the 2017 NEI.

29 MWC facilities located in non-transport states (states not affected by the proposed FIP) equaled 17,968 tons in 2017.

Table 8: NOx Emissions from MWC Facilities Located in States Affected by Proposed FIP

Units = Tons/Year for 2017

STATE	FACILITY	CITY	EMISSIONS
CA	COVANTA STANISLAUS, INC	CROWS LANDING	290.1
CA	LONG BEACH CITY, SERRF PROJECT	LONG BEACH	268.7
CA	COMMERCE REFUSE TO ENERGY FACILITY	COMMERCE	95.7
IN	COVANTA INDIANAPOLIS INC	INDIANAPOLIS	1,122.0
MD	Wheelabrator Baltimore, LP	Baltimore	1,101.2
MD	Montgomery County RRF	Dickerson	441.7
MI	DETROIT RENEWABLE POWER, LLC	DETROIT	1,212.4
MI	Kent County Waste to Energy Facility	GRAND RAPIDS	342.0
MN	Xcel Energy - Red Wing Generating Plant	Red Wing	593.3
MN	Xcel Energy - Key City/Wilmarth	Mankato	498.4
MN	Hennepin Energy Recovery Center	Minneapolis	411.7
MN	Great River Energy	Elk River	391.7
MN	Olmsted Waste-to-Energy Facility	Rochester	140.7
MN	Pope/Douglas Solid Waste Management	Alexandria	138.2
MN	Perham Resource Recovery Facility	Perham	74.3
MN	Polk County Solid Waste Facility	Fosston	31.4
NJ	Covanta Essex Company	NEWARK	762.7
NJ	Union County Resource Recovery Facility	RAHWAY	613.3
NJ	Camden County Energy Recovery Associates L.P.	CAMDEN	375.8
NJ	WHEELABRATOR GLOUCESTER COMPANY L P	WESTVILLE	240.3
NJ	Covanta Warren Energy Resource Co. L.P.	OXFORD	170.0
NY	HEMPSTEAD RESOURCE RECOVERY FACILITY	WESTBURY	1,111.0
NY	WHEELABRATOR WESTCHESTER LP	PEEKSKILL	1,046.7
NY	COVANTA NIAGARA LP	NIAGARA FALLS	748.2
NY	ONONDAGA CO RESOURCE RECOVERY FACILITY	JAMESVILLE	541.0
NY	HUNTINGTON RESOURCE RECOVERY FACILITY	E NORTHPORT	357.3
NY	WHEELABRATOR HUDSON FALLS	HUDSON FALLS	237.6
NY	BABYLON RESOURCE RECOVERY FACILITY	WEST BABYLON	183.7
NY	ISLIP MCARTHUR RESOURCE RECOVERY FACIL	RONKONKOMA	157.4

NY	DUTCHESS CO RESOURCE RECOVERY FACILITY	POUGHKEEPSIE	148.5
NY	OSWEGO CO ENERGY RECOVERY FAC	FULTON	148.0
OK	WALTER B HALL RESOURCE RECOVERY FACLTY	TULSA	518.5
PA	COVANTA DELAWARE VALLEY LP/DELAWARE VALLEY RES REC	CHESTER	1,236.6
PA	WHEELABRATOR FALLS INC/FALLS TWP	MORRISVILLE	688.1
PA	COVANTA PLYMOUTH RENEWABLE ENERGY/ PLYMOUTH	CONSHOHOCKEN	660.5
PA	LANCASTER CNTY RRF/ LANCASTER	BAINBRIDGE	517.1
PA	YORK CNTY SOLID WASTE/YORK CNTY RESOURCE RECOVERY	YORK	449.0
PA	LANCASTER CNTY SWMA/SUSQ RESOURCE MGMT COMPLEX	HARRISBURG	196.3
PA	SCRANTON ARMY AMMUNITION PLT/SCRANTON CITY	SCRANTON	11.4
VA	Wheelabrator Portsmouth Inc, RDF Facility	Portsmouth	1,324.5
VA	Covanta Alexandria/Arlington Inc	Alexandria	461.5
VA	Covanta Fairfax Inc	Lorton	174.2
VA	Hampton/NASA Steam Plant	Hampton	111.5
		Total	**20,344.1**

Summary of Federal NSPS and Emission Guideline NOx limits.

EPA has promulgated NOx emission limits for large MWCs, defined as those that process 250 tons of municipal solid waste per day or more at 40 CFR Part 60, Subpart Cb and 40 CFR Part 60, Subpart Eb. Subpart Cb is applicable to MWCs that commenced construction on or before September 20, 1994, while Subpart Eb is applicable to MWCs that commenced construction, modification, or reconstruction after September 20, 1994. The NOx limits for Subpart Cb are found within Tables 1 and 2 of 40 CFR 60.39b and range from 165 to 250 ppm depending on the combustor design type. The NOx limits for Subpart Eb are found at 40 CFR 60.52b(d) and are 180 ppm during a unit's first year of operation and drop to 150 ppm afterwards, applicable across all combustor types.

NOx limits adopted by states for MWCs.

Section 182(b)(2) and (f) of the CAA requires states containing moderate or above ozone nonattainment areas to adopt regulations with control requirements representing reasonably available control technology (RACT) for major sources of volatile organic compounds (VOCs) and NOx, and sections 184(b)(1)(B) and 182(f) of the Act require RACT control requirements be adopted in all areas included within an Ozone Transport Region (OTR). Due primarily to the NOx RACT requirement, many states within the Northeast located within the OTR have adopted

NOx emission limits for MWCs that are more stringent than what would otherwise be required by EPA's NSPS or emissions guideline for these units. For example, the Montgomery County Resource Recovery Facility in Maryland is required to meet a NOx RACT limit of 140 ppm (@ 7% oxygen) on a 24-hour block average. Additionally, MWC facilities located in Virginia operated by Covanta, Inc., are required to meet a NOx RACT limit of 110 ppm (@ 7% oxygen) on a 24-hour basis, and a limit of 90 ppm (@ 7% oxygen) on an annual average basis.[86]

Emissions and control options outlined within a June 2021 report from the OTC

The OTC issued a report entitled "Municipal Waste Combustor Workgroup Report" in June of 2021. The report is included within the Docket for this proposal. The report notes that MWCs are a significant source of NOx emissions in the OTR, releasing approximately 22,000 tons of NOx from facilities within 9 OTR states in 2018. The report summarizes the results of a literature review of state-of-the-art NOx controls that have been successfully installed on MWCs and concludes that significant reductions could be achieved using several different technologies described in the report, primarily via combustion modifications made to MWC units already equipped with SNCR. The MWC workgroup evaluated the emission reduction potential from two different control levels, one based on a NOx concentration in the effluent of 105 to 110 ppm, and another based on a limit of 130 ppm. The workgroup's findings were that a control level of 105 ppmvd on a 30-day average basis and a 110 ppmvd on a 24-hour averaging period would reduce NOx emissions from MWCs by approximately 7,300 tons annually, and that a limit of 130 ppmvd on a 30 day-average could achieve a 4,000 tons reduction. The report notes that 8 MWC units exist that are already subject to permit limits of 110 ppm, 7 in Virginia, and one in Florida. Studies evaluating MWCs similar in design to the large MWCs in the OTR found NOx reductions could be achieved at costs ranging from $2,900 to $6,600 per ton of NOx reduced. Based on the findings of this report, the Commissioners of the states within the OTR adopted a resolution to develop a recommendation for emission reductions from MWCs during their June 15, 2021 annual public meeting.[87]

The OTC's MWC workgroup report describes a literature review to identify additional control technologies to reduce NOx emissions from large MWCs. Based on that review, two control technologies emerged as potentially technically and economically feasible options to achieve the control levels of 105 ppm on a 30-day average basis and a 110 ppm on a 24-hour averaging period: Covanta's "Low-NOx (LN^{TM}) technology" and advanced selective non-catalytic reduction (ASNCR).

Covanta's LN^{TM} Process

Covanta's LN^{TM} process is a trademarked system which modifies the secondary air (also called overfire air) stream. To complete the combustion process in the MWC furnace, the secondary air is injected through nozzles located in the furnace side walls above the grate to allow turbulent mixing. With the LN^{TM} process, a tertiary air stream is introduced by diverting a

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[86] The NOx permit limits for the Montgomery County facility and the Virginia facilities can be found within the OTC's Municipal Waste Combustor Workgroup Report included within the Docket for this action.

[87] See "Notice of Actions Taken by Ozone Transport Commission At Annual Public Meeting, June 15, 2021" included in the Docket for this action.

portion of secondary air through a new series of air nozzles located higher in the furnace. By controlling the distribution of air between the primary, secondary, and tertiary streams, the optimal gas composition and temperature is achieved to minimize NOx formation. With complete coverage of the furnace cross-section, the tertiary air stream ensures good mixing with the combustion gases. During the $\mathrm{LN}^{\mathrm{TM}}$ process, only the distribution of air is altered. The total air flow to the MWC is left unchanged.

Approximately 20 units have installed or been retrofitted with the $\mathrm{LN}^{\mathrm{TM}}$ process, including the two Covanta facilities located in Virginia. However, since the $\mathrm{LN}^{\mathrm{TM}}$ technology is proprietary, it is available only to Covanta facilities.

Advanced Selective Non-Catalytic Reduction (ASNCR)

The OTC's MWC report describes a report conducted by Babcock Power for the Wheelabrator Baltimore facility that evaluated several potential NOx control technologies, including ASNCR. ASNCR, like SNCR, involves the injection of reagents (typically ammonia or urea) into the proper temperature zone of the furnace to reduce the NOx concentration within the flue gas. ASNCR also utilizes Computational Fluid Dynamics (CFD) modeling and Chemical Kinetic Modeling (CKM) technology along with real-time furnace temperature maps to modulate which injectors are in operation and the reagent flow rates. This not only significantly decreases NOx emissions but ensures a low ammonia slip (around 5 ppm). ASNCR is currently being installed at Wheelabrator Baltimore and is available to non-Covanta facilities. In addition to the two NOx control technologies described above, the Babcock report also reviewed other NOx control options including optimized SNCR, flue gas recirculation SNCR (FGR-SNCR), and FGR-ASNCR.

OTC Report's Evaluation of Control Costs

The OTC's MWC report also evaluated the cost for the installation and operation of the control technologies. The cost effectiveness for $\mathrm{LN}^{\mathrm{TM}}$ technology were based off of two RACT analyses by Trinity Consultants for the Covanta Alexandria/Arlington and Covanta Fairfax facilities in Virginia. These reports assessed the total capital investment expenditures for the $\mathrm{LN}^{\mathrm{TM}}$ technology, which includes direct cost (purchasing the equipment) and indirect costs (installation and lost production resulting from extended downtime due to installation). The costs from the installation of the $\mathrm{LN}^{\mathrm{TM}}$ technology at the Covanta facility in Montgomery County, MD were used to estimate the costs for Covanta Alexandria/Arlington and Covanta Fairfax. Capital cost were annualized, based on projected lifetime of 20 years and a 7% interest rate, and added to the annual operating cost to determine the total yearly costs.[88]

Although the Trinity Consultants reports assumed a controlled NOx value of 90 ppm (the new annual NOx limit at the two Virginia facilities), the OTC's MWC workgroup estimated the cost reduction for a 110 ppm 24-hour limit. This was done because the amount of reagent used and operations and maintenance costs are likely to be higher to achieve a 90 ppm limit, as compared to a 110 ppm 24-hour limit. This resulted in a price decrease of $0.89 per pound of

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[88] We note that the OTC white paper did not provide a year dollars for the total yearly costs, nor for the cost per NOx reduced estimates quoted from the white paper.

NOx reduced, per information contained in the Babcock report for the Wheelabrator Baltimore facility.

The OTC's MWC workgroup then calculated the projected NOx emission reduction based on a 110 ppm limit. To determine the cost effectiveness, the total yearly costs were divided by the NOx emission reduction. Overall, the 110 ppm 24-hour NOx limit cost effectiveness for LN^{TM} technology ranged from $2,900 to $4,639 per ton of NOx reduced.

The OTC's MWC report also evaluated the cost effectiveness of ASNCR to control NOx emissions at MWCs. Cost effectiveness calculations for ASNCR were based off the Babcock report. To evaluate the annualized capital cost, the workgroup utilized a formula from EPA Air Pollution Control Cost Manual and its *Chapter 2 – Cost Estimation: Concepts and Methodology (*US EPA, 2017). Like the Trinity Consultants RACT analyses, a projected lifetime of 20 years and a 7% interest rate were assumed to estimate the annualized capital cost. Also, as with the LN^{TM} technology, the NOx emission reduction for ASNCR was based on a 110 ppm 24-hour limit. For ASNCR, the 110 ppm 24-hour NOx limit cost effectiveness was $6,159 per ton of NOx reduced.

8 Feasibility and Installation Timing

EPA proposes to require that the non-EGU controls discussed in this TSD be installed and operational by the 2026 ozone season and to find that any earlier date is not possible. EPA previously examined the time necessary to install the controls identified for several non-EGU industries. Although the information on installation times for most NO_X controls applied to glass and cement manufacturing was uncertain, EPA identified minimum estimated installation times for a number of other non-EGU source categories that ranged from several weeks to slightly over a year. This included timeframes of 42–51 weeks for SNCR applied to dry cement manufacturing facilities and cement kilns/dryers burning bituminous coal, 28-58 weeks for SCR applied to boilers and process heaters, 28-58 weeks for SCR applied to iron and steel in-process combustion, and 6-8 months for low NO_X burners and flue gas recirculation at iron and steel mills.[89] Taking into account necessary scale-up of construction services for multiple control installations at several emissions units, the time needed to have NO_X monitoring installed and operating, and other necessary steps in the permitting and construction processes (e.g., review of vendor bids), EPA estimates an additional period of 6 to 18 months may be necessary for existing non-EGU sources to install the necessary controls, depending on the number of control installations at a facility.[90]

Additionally, EPA previously considered the installation timing needs for NO_X controls (including SCR, SNCR, and combustion controls) at both EGU and non-EGU sources as part of the 1998 NO_X SIP Call.[91] With respect to combustion controls (e.g., low-NO_X burners, overfire air, etc.), EPA found that sources should be able to complete control technology installations and obtain relevant permits in relatively short timeframes given considerable experience at that time among sources and permitting agencies with the implementation of such controls, the fact that combustion controls are constructed of commonly available materials (steel, piping, etc.) and do not require reagent during operation, and the then availability of many vendors of combustion control technology.[92]

With respect to post-combustion controls (primarily SCR and SNCR), EPA considered three basic factors in assessing installation timing needs: (1) availability of materials and labor, (2) the time needed to implement controls at plants with single or multiple retrofit requirements, and (3) the potential for interruptions in power supply resulting from outages needed to complete installations on EGUs.[93] Assuming adequate supplies of both off-the-shelf hardware (such as steel, piping, nozzles, pumps, and related equipment) and the catalyst used in the SCR process, as well as sufficient vendor capacity to supply retrofit SCR catalyst to sources, and taking into account the additional time needed for facility engineering review, developing control

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[89] Final Technical Support Document (TSD) for the Final Cross-State Air Pollution Rule for the 2008 Ozone NAAQS, Assessment of Non-EGU NO_X Emissions Controls, Cost of Controls, and Time for Compliance Final TSD ("CSAPR Update Non-EGU TSD"), August 2016 (Table 3), available at *https://www.epa.gov/csapr/assessment-non-egu-*NOX*-emission-controls-cost-controls-and-time-compliance-final-tsd*. See also Institute of Clean Air Companies, SNCR Committee, "White Paper, Selective Non-Catalytic Reduction (SNCR) For Controlling NOx Emissions," at 5 (noting that "SNCR retrofits typically do not require extended source shutdowns").

[90] 63 FR 57356, 57448 (October 27, 1998).

[91] Id. at 57447-57449.

[92] Id. at 57447, 57449.

[93] Id. at 57448.

technology specifications, awarding a procurement contract, obtaining a construction permit, completing control technology design, installation, and testing, and obtaining an operating permit, EPA found that (a) about 21 months would be needed to implement an SCR retrofit on a single unit and (b) about 19 months would be needed to implement an SNCR retrofit on a single unit.[94] EPA also examined several particularly complicated implementation efforts and found that 34 months would be needed for a plant to install a maximum of 6 SCRs while 24 months would be needed for a plant to install a maximum of 10 SNCRs.[95] Finally, EPA found that the necessary controls could be installed on EGUs without any disruptions in the supply of electricity because connections between a NOx control system and a boiler can generally be completed in 5 weeks or less and thus could occur during the 5-week planned outage that each EGU typically has each year.[96]

Thus, for both EGUs and non-EGUs, EPA's technical analysis for the 1998 NOX SIP Call indicated that a three-year period would be sufficient for installation of both combustion and post-combustion controls, from the planning and specification of controls to completion of control technology implementation.[97] EPA's evaluation of the timeframes for post-combustion controls was based on the Agency's projection that 639 retrofit installations at EGU sources and 235 retrofit installations at non-EGU industrial sources would be necessary for existing sources in the covered states to comply with the NOX SIP Call.[98] Although the scope of non-EGU sources covered by this proposed FIP is broader, and the number of emissions units is greater, than the scope and number of non-EGU sources evaluated in the 1998 NOX SIP Call, and although a later analysis of timeframes for installation of post-combustion controls at EGUs produced a more refined estimate for that sector only,[99] EPA's prior analyses nonetheless inform the evaluation in this proposal of the necessary implementation schedule for non-EGU sources given they generally address NOX control technologies similar to those that EPA anticipates non-EGU sources may install to comply with the provisions of the proposed FIP (e.g., SCR, SNCR, low-NOX burners and ultra-low NOX burners).

Additionally, as part of EPA's evaluation of installation timing needs in the proposed CAIR (69 FR 4566), EPA projected that it would take on average 21 months to install an SCR on one EGU unit, 27 months to install a scrubber on one EGU unit, and three years to install seven SCRs at a single EGU. [100] EPA also noted that some EGUs could install SCR controls in as short of a period as 13 months.[101] This information and EPA's general experience indicate that a two-year installation timeframe for a rule requiring installation of new control technologies across a variety of emissions sources in several industries on a regional basis is a relatively fast installation timeframe, but that a three-year installation timeframe should be feasible for most if

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[94] Id.

[95] Id.

[96] Id.

[97] Id. at 57449.

[98] Id. at 57448 (Table V-1 and Table V-2).

[99] See Final Report, "Engineering and Economic Factors Affecting the Installation of Control Technologies for Multipollutant Strategies," EPA-600/R-02/073 (October 2002).

[100] 69 FR 4566, 4617 (January 30, 2004) (citing Final Report, "Engineering and Economic Factors Affecting the Installation of Control Technologies for Multipollutant Strategies," EPA-600/R-02/073 (October 2002)).

[101] Final Report, "Engineering and Economic Factors Affecting the Installation of Control Technologies for Multipollutant Strategies," EPA-600/R-02/073 (October 2002), at 21.

not all of the identified industries. A shorter installation timeframe of approximately one year would likely raise significant challenges for sources, suppliers, contractors, and other economic actors, potentially including customers relying on the products or services supplied by the regulated sources. Thus, if EPA finalizes this proposed rule in 2023, implementation of the necessary emissions controls across all of the affected non-EGU sources by the August 3, 2024 Moderate area attainment date would not be possible.

For purposes of this proposed rule, EPA estimates that the required controls for non-EGU source categories would take up to three years to install across the affected industries in the 23 states that remain linked in 2026. Therefore, based on the available information, EPA proposes to require compliance with these non-EGU control requirements by the beginning of the 2026 ozone season.

EPA requests comment on the time needed to install the various control technologies across all of the emissions units in the Tier 1 and Tier 2 industries. In particular, EPA solicits comment on the time needed to obtain permits, the availability of vendors and materials, design, construction, and the earliest possible installation times for SCR on glass furnaces; SNCR or SCR on cement kilns; ultra-low NO_X burners, low NO_X burners, and SCR on ICI boilers (coal-fired, gas-fired, or oil-fired); low NO_X burners on large non-EGU ICI boilers; and low emissions combustion, layered emissions combustion, NSCR, and SCR on reciprocating rich-burn or lean-burn IC engines.

With respect to emissions monitoring requirements, EPA requests comment on the costs of installing and operating CEMS at non-EGU sources without NO_X emissions monitors; the time needed to program and install CEMS at non-EGU sources; whether monitoring techniques other than CEMS, such as predictive emissions monitoring systems (PEMS), may be sufficient for certain non-EGU facilities, and the types of non-EGU facilities for which such PEMS may be sufficient; and the costs of installing and operating monitoring techniques other than CEMS.

EPA also requests comment on whether the FIP should provide a limited amount of time beyond the 2026 ozone season for individual non-EGU sources to meet the emissions limitations and associated compliance requirements, based on a facility-specific demonstration of necessity. As the D.C. Circuit stated in *Wisconsin*, the good neighbor provision may be read to allow for some deviation from the mandate to eliminate prohibited transport by downwind attainment deadlines, "under particular circumstances and upon a sufficient showing of necessity," provided such deviation is "rooted in Title I's framework [and] provide[s] a sufficient level of protection to downwind States."[102] Consistent with this directive, and recognizing that in general, EPA aligns good neighbor obligations in the first instance with the last full ozone season before the downwind attainment date, EPA requests comment on whether individual non-EGU sources should be allowed to request an extension of the May 1, 2026 compliance deadline by no more than 1 year (i.e., to May 1, 2027) based on a sufficient showing of necessity. Any such comments should be supported by a detailed discussion of the facility-specific economic, technological, and other circumstances that may justify such an extension. EPA notes that claims about infeasibility of controls are generally insufficient to justify an extension of time to comply, given the

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[102] *Wisconsin,* 938 F. 3d at 320 (citing CAA section 181(a) (allowing one-year extension of attainment deadlines in particular circumstances) and *North Carolina*, 531 F.3d at 912).

Wisconsin court's holding that the good neighbor provision requires upwind states to eliminate their significant contribution in accordance with the downwind states' attainment deadlines, without regard to questions of feasibility.[103]

EPA further solicits comment on the specific criteria that EPA should apply in evaluating requests for extension of the 2026 compliance deadline for non-EGU sources. Such criteria could include documentation of inability, despite best efforts, to procure necessary materials or equipment (e.g., equipment manufacturers are not able to deliver equipment before a specific date) or hire labor as needed to install the emissions control technology by 2026; documentation of installation costs well in excess of the highest representative cost-per ton threshold identified for any source (including EGUs) discussed in Section VI (e.g., vendor estimate showing equipment cost); documentation of a source owner or operator's inability to secure necessary financing, due to circumstances beyond the owner/operator's control, in time to complete the installation of controls by 2026; or documentation of extreme financial or technological constraints that would require the subject non-EGU emissions unit or facility to significantly curtail its operations or shut down before it could comply with the requirements of this proposed rule by 2026. Finally, EPA requests comment on the process through which EPA should review and act on an extension request—e.g., the appropriate deadline for submitting a request, and whether EPA should provide an opportunity for public comment before granting or denying a request.

EPA anticipates that the owner or operator of the facility would bear the burden of establishing the necessity of an extension of time to comply, based on particular circumstances described and sufficiently documented in the submitted request. Claims of generalized financial or economic hardship or any claim that controls are not necessary to eliminate significant contribution would not suffice to justify an extension. If EPA finalizes a provision allowing sources to request limited extensions of time to comply, the Agency would review each request on a case-by-case basis as necessary to ensure consistency with the provisions of title I of the CAA.

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[103] *Wisconsin,* 938 F.3d at 313-314, 319 ("When an agency faces a statutory mandate, a decision to disregard it cannot be grounded in mere infeasibility"). We note also that in the CSAPR Close-Out Rule (83 FR 65878, December 21, 2018), EPA required no further reductions from upwind states beyond those set forth in the prior CSAPR Update based, in part, on the Agency's conclusion that it was not feasible to implement cost-effective emissions controls before 2023, two years after the 2021 attainment deadline for the downwind serious areas. The D.C. Circuit vacated the Close-Out Rule for its reliance on the same interpretation of the Good Neighbor Provision that the court had rejected in *Wisconsin. New York v. EPA,* 781 F. App'x 4 (D.C. Cir. 2019) (unpublished opinion).