www.erg.com

MEMORANDUM

TO: Lisa Thompson
U.S. EPA/Office of Air Quality Planning and Standards
Sector Policies and Programs Division

FROM: Eastern Research Group, Inc. (ERG)

DATE: August 2021

SUBJECT: Revised (2021) Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants – Major Source

---

1.0 Introduction

This memorandum discusses the algorithms and inputs used to estimate capital and annual control costs for the final changes to emission limits for the Major Source Industrial, Commercial, and Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. Capital and annualized cost impacts were calculated for add-on control technologies, increase in reagent for existing control technologies, and testing and monitoring. The add-on control costs were estimated for each impacted individual boiler and process heater based on a combination of reported and standardized data, including fuel types, unit sizes, current control devices, and baseline emission values. Characteristics necessary to estimate control costs were assigned to specific units based on data reported by industry to the Compliance and Emissions Data Reporting Interface (CEDRI) and WebFIRE, hereinafter referred to as boiler compliance data. The control cost algorithms did not change substantially since the analysis was completed for the 2013 final rule. However, some constants were updated to reflect more recent costs.

This memorandum is organized as follows:

1.0 Introduction

2.0 Inputs for Cost Algorithms

3.0 Cost Algorithms for Add-on Control Devices

2.0 Inputs for Cost Algorithms

Add-on control technologies are those that are applied to the vent gas stream of an emissions unit, such as a boiler, to reduce emissions before the stream enters the atmosphere. The boiler compliance data include information on control devices currently installed on each combustion unit and the emission levels achieved during a performance test. The control strategy to meet the finalized more stringent emission limits included the following controls: fabric filter, electrostatic precipitator (ESP), packed bed scrubber, dry injection/ fabric filter systems (DIFF). In addition, for units that reported to have a scrubber already installed, the impacts analysis also analyzed the costs of increasing the caustic flowrate on an existing scrubber in order to improve scrubber efficiency.

2.1 Components of Control Cost Algorithms

When add-on technologies are used, consideration must be given to added expenses such as ductwork and associated equipment. The discussion of the algorithms used to calculate capital and annual costs of these devices and the inputs to the algorithms are presented in this section.

Components of capital costs incorporated into the algorithms include:

- Purchased equipment cost of the primary device and auxiliary equipment
- Instrumentation
- Sales tax and freight
- Installation costs including structural needs such as foundations and support, handling and erection, piping, insulation, painting, engineering, construction, field expenses, contractor fees, start-up, performance tests, and contingencies

Components of annual cost include:

- Raw materials (e.g., catalysts)
- Utilities (e.g., electricity, fuel, steam, air, water)
- Waste treatment and disposal
- Labor (operating, supervisory, maintenance)
- Maintenance materials
- Replacement parts
- Overhead
- Property taxes
- Insurance
- Administration charges
- Capital recovery costs[1]

For this analysis, all compliance costs were estimated in 2016 dollars and the total capital investment of control device and monitoring costs are annualized using a nominal interest rate of 5.5 percent over the life of the equipment. This nominal interest rate is the same as that used in the proposal cost analysis, and we use the same rate to allow for greater comparability of annualized costs for the final rule to those of the proposal.[2] Costs originally provided in years other than 2016 were escalated to 2016 dollars using the Chemical Engineering Plant Cost Index (CEPCI).

The interest rate used to annualize the capital costs of compliance for affected facilities in this cost analysis is a measure of the cost of financing by debt the purchase and installation of emissions control equipment. This rate is not the same as the hurdle rate, which is the minimum rate a company requires earning based on their own criteria for investing in a project.[3] We are not able to find or determine the cost of capital that each firm directly affected by this action would use when choosing between pollution control methods. The literature on hurdle rates has

[1] These capital and annual cost components applied for cost estimation for each control device included in the analysis are consistent with those in the current Cost Estimation methodology chapter (Section 1, Chapter 2) of the EPA Air Pollution Control Cost Manual, 7th Edition, November 2017.
[2] We note that the interest rate used in this analysis is higher than the bank prime rate, which is 3.0-3.25% as of July 2021. The current bank prime rate is normally recommended for use in annualizing capital costs of rulemakings as mentioned in the EPA Air Pollution Control Cost Manual, 7th Edition, Section 1, Chapter 2.
[3] The hurdle rate can also be referred as a target rate or a required rate of return of investment needed to meet the company's objectives. The minimum hurdle rate is usually the company's cost of capital (a blend of the cost of debt and the cost of equity). The hurdle rate includes a risk premium – that is, some appropriate compensation for the risk present in an investment. Therefore, the hurdle rate will be higher for projects with greater risk and when the company has an abundance of investment opportunities.

found difficulties in finding or determining specific hurdle rates at various companies, and that hurdle rates may be relatively insensitive to interest rates.[4] Because of this, the analysis of compliance costs for this final rule does not account for the possible hurdle rates for the affected companies.

If hurdle rates were considered as part of the compliance cost analysis, then this potentially may lead to different compliance choices, especially for those compliance choices that are relatively capital-intensive, more-so than those included in this analysis. However, as mentioned in the impacts memo for this final rule, there is a limited choice of potential compliance options for affected ICI boilers.[5] The EPA reviewed compliance data dating back to 2013, the year the ICI boiler Maximum Achievable Control Technology (MACT) in the baseline was promulgated, using the CEDRI and WebFIRE databases, which are databases maintained by EPA, where electronic compliance data such as performance test reports, notifications of compliance status, and continuous emission monitoring system (CEMS) data is submitted to EPA. This review covered 577 existing boilers, of which 485 remain operational and in a subcategory subject to emission limits, and 15 new boilers subject to emission limits. These compliance data for major hazardous air pollutant (HAP) sources includes the control devices in place on these boilers as of December 2020,[6] and the selection of control devices employed in this analysis are based on this compliance data. Each control device is the predominant one used for control of a particular pollutant for those boilers subject to this final rule, and no other control devices were found to be available to serve as alternatives in the analysis to meet the final emissions limits. For example, the use of fabric filters for mercury control "was expected to achieve most of the [mercury] emission reductions in the final rule."[7] Given that there are limited compliance options for these boilers, it may be that the application of hurdle rates would not lead to significantly different compliance choices or costs for the boilers impacted from what was concluded in the private compliance cost analysis. In order to address this issue, we estimated the

---

[4] See "The Insensitivity of Investment to Interest Rates: Evidence from a Survey of CFOs." Sharpe, Steven and Suarez, Gustavo. Working Paper. Washington, D.C., Federal Reserve Board, Division of Research and Statistics and Monetary Affairs. December 3, 2013. Available at https://www.federalreserve.gov/pubs/feds/2014/201402/201402pap.pdf.

[5] U.S. EPA. Revised (2019) Methodology for Estimating Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. Prepared by Eastern Research Group (ERG). August 2019.

[6] U.S. EPA. WebFIRE database. Available at https://www.epa.gov/electronic-reporting-air-emissions/webfire. Accessed on January 1, 2021.

[7] U.S. EPA. Revised (2021) Methodology for Estimating Impacts for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants. ("Impacts memo"). Prepared by Eastern Research Group (ERG). August 2021.

compliance costs using nominal interest rates that are higher than the rate applied in the main cost analysis, 10% and 15%, respectively, as sensitivity analyses. We find that the choice of compliance options is insensitive to the selection of interest rates as applied in this analysis. Thus, we find that the application of nominal interest rates of up to 15% do not change the selection of compliance options for this final rule. This implies that the hurdle rate for these investments in compliance options, while unknown, may be lower than the rates included in these cost analyses. These results are presented and discussed in the final rule's Impacts memo and Appendices B-1 and B-2 for that memo.

Table 1 lists the costs for components common to the costing algorithms for multiple control devices, along with the source of the information.

Table 1: Costs of Common Components Used in Cost Estimate Algorithms

Cost Component	Cost (2016$)	Source
Weighted Labor Rate	60.07	U.S. Dept. of Labor—Bureau of Labor Statistics
Electricity ($/kWh)	0.069	U.S. Energy Information Administration, avg. of industrial prices
Water ($/gal)	0.001	U.S. Dept. of Energy
Wastewater Disposal ($/gal)	0.007	U.S. Dept. of Energy
Cost Factor for Sodium Bicarbonate	141	USGS
Dust Disposal ($/ton)	48	Waste360
Compressed Air ($/1000 ft^3)	0.47	Hydraulics & Pneumatics 2016
Cost factor for Lime ($/ton)	144	Lime cost: U.S. Geological Survey. Mineral Commodity Summaries 2017. Hydrated Lime Average Value, 2016

The labor rate was based on the May 2016 hourly mean wage reported for occupational codes for Stationary Engineers and Boiler Operators (Standard Occupational Classification (SOC) code 518021) across the following four industries: Electric Power Generation, Transmission and Distribution (221100); Pulp, Paper and Paperboard Mills (322100); Chemical Manufacturing (325000); and Colleges, Universities and Professional Schools (611300). All of these industries have several facilities expected to be subject to the finalized standards. The average raw wage for these four industries was $28.60/hour, and to account for benefits and overhead, a factor of 110 percent of the raw wage was applied to estimate a loaded hourly wage.

The cost algorithms for the control devices were identical to the algorithms used for the 2013 final rule.[8] The EPA Air Pollution Control Cost Manual (CCM) contains the detailed cost procedures and algorithms for each control device. The appendices to this memorandum include cost algorithms reduced/simplified to basic equations from the EPA studies.

Installing air pollution control devices on existing boilers requires additional costs to retrofit the equipment. These costs are not included in the cost estimates of the CCM or other sources. For this analysis, a retrofit factor of 1.4 was applied to the costs of installing a fabric filter, packed-bed scrubber, dry injection/fabric filter, and ESP as well as any duct work associated with the installation of these control devices. A factor of 1.3 in the EPA CueCost model represents a retrofit of medium difficulty, but for some of these smaller sources, commenters noted that retrofit may be more difficult than average due to limited space.

2.2 Inputs to Control Cost Algorithms

The inputs required to estimate the cost impacts include primary fuel type; exhaust gas flow rate (on both an actual and dry standard basis); flue gas temperature, oxygen, and moisture; baseline emissions entering the control device; target MACT floor emission rate or concentration; unit design capacity; and hours of operation. These inputs were either reported by industry in their compliance data, or they were calculated from the reported data. While the hours of operation vary depending on the unit, the algorithms all used an estimate of 8,424 per year, or 96.2% of total operating capacity, for operating hours in the calculations.

Excess Air and Exhaust Temperature

For exhaust conditions, assumptions were made consistent with the assumptions used in the 2013 final rule. Coal model units less than 400 MMBtu/hr were assigned a typical excess air value of 50 percent and an exhaust temperature of 400°F. Coal model units greater than 400 MMBtu/hr were assigned a typical excess air value of 30 percent and an exhaust temperature of 400°F. Biomass units were assigned a typical excess air value of 50 percent and an exhaust temperature of 400°F.

[8] See: Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emission Standards for Hazardous Air Pollutants - Major Source. Docket ID Item No. EPA-HQ-OAR-2002-0058-3268

Exhaust Flowrate, Moisture and Percent Oxygen

Information on exhaust gas flowrate, moisture content, and percent oxygen for boilers and process heaters was reported in the Boiler Survey[9] on a limited basis, or in most cases, was not available. Therefore, these parameters were calculated from the combustion kinetics of burning the primary fuels. For this calculation, the hydrogen, carbon, nitrogen, oxygen, and water composition of the primary fuel is necessary.

The primary fuel of each boiler and process heater was identified according to compliance data reported. Next, each fuel category was assigned a fuel composition, as indicated in Table 2.

Table 2: Boiler and Process Heater Fuel Categories in Boiler Survey Database[10] and their Corresponding Fuel Composition Equations

Fuel Category	Fuel Composition Assumption for Combustion Kinetics Calculations
Coal	Sub-bituminous
Coal	Sub-bituminous over 400 MMBtu/hr
Dry Biomass	Biomass (dry)
Wet Biomass, Bagasse	Biomass (wet)

An average heating value and material analysis data (in percent by weight) were obtained for hydrogen, carbon, nitrogen, ash, sulfur, and oxygen for each fuel.[11] These average percentages and the elements' molecular weights were used to calculate the theoretical amount of oxygen (in moles per hundred pounds of fuel [mole/100 lb fuel]) necessary for the combustion of the fuel. An example calculation is provided in Appendix A.

3.0 Cost Algorithms for Add-on Control Devices

3.1 Fabric Filter

Fabric filters offer emission control for mercury (Hg), particulate matter (PM), and non-Hg metallic HAP. The algorithms used to estimate capital and annual costs of fabric filters were identical to those used in the 2013 final rule. These algorithms were originally based on those

[9] Survey Database Containing Results of the 2008 Questionnaire. The latest database containing the compiled answers is at Docket ID: EPA-HQ-OAR-2002-0058-3830.
[10] Ibid.
[11] Babcock and Wilcox. *Steam its generation and use 40th edition*. 1992.

used in the October 2008 memo entitled *Compliance Costs and Economic Inputs for Existing Hospital/Medical/Infectious Waste Incinerators*.[12] The cost algorithms for estimating annual and capital costs are provided in Appendix B. The algorithms estimate the costs for a pulse-jet type fabric filter using felt bags. When fabric filters are applied to certain boilers designed to fire biomass fuels, a flame-retardant spray may be required to reduce fire hazards. The cost for the flame retardant has not been included in this cost analysis. Capital costs are based on the gross cloth area of the fabric filter, which is a function of the gas inlet flowrate. Annual costs include dust disposal, electricity, maintenance, labor, bag replacement, maintenance labor, compressed air, capital recovery costs, overhead, administrative costs, property taxes, and insurance.

3.2 Dry Injection/Fabric Filter (DIFF)

The inclusion of dry injection prior to a fabric filter offers emission control for hydrogen chloride (HCl). The algorithms used to estimate capital and annual costs of DIFF systems were identical to those used in the 2013 final rule. The algorithms were originally based on the October 2008 memo entitled *Compliance Costs and Economic Inputs for Existing Hospital/Medical/Infectious Waste Incinerators*.[13] The cost algorithms for estimating annual and capital costs are provided in Appendix F. The algorithms estimate the capital cost of the equipment based on the exhaust flowrate. Annual costs include lime, water, dust disposal, electricity, maintenance, labor, bag replacement, maintenance labor, compressed air, capital recovery costs, overhead, administrative costs, property taxes, and insurance.

3.3 Electrostatic Precipitator

Electrostatic Precipitators (ESPs) are commonly used to control PM and metallic HAP emissions. The algorithms used to estimate capital and annual costs of ESPs are identical to those in the 2013 final rule and originally came from the ESP chapter in the CCM.[14] The ESP costs are based on a cold-side, dry-type ESP. Few, if any, hot-side ESPs are being specified for purchase. Capital costs are based on the total collection plate area, which is calculated from the gas inlet flowrate and the required removal efficiency. The cost algorithms for estimating capital and annual costs of ESPs reduced to basic equations are provided in Appendix C-1. Annual costs

---

[12] Holloway, Thomas. RTI International, Memo to Mary Johnson, U.S. Environmental Protection Agency, Compliance Costs and Economic Inputs for Existing HMWI. October 24, 2008. See Docket ID Item No. EPA-HQ-OAR-2006-0534-0325.

[13] Ibid.

[14] U.S. Environmental Protection Agency, EPA Air Pollution Control Cost manual, Sixth Edition. EPA/452/B-02-001, January 2002. Section 6. Chapter 3. https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution.

include dust disposal, electricity, maintenance materials, operating labor, maintenance labor, capital recovery costs, overhead, administrative, property taxes, and insurance. Appendix C-2 presents the values for the inputs used in this analysis.

3.4 Packed Bed Scrubber

Packed bed scrubbers are generally used to lower emissions of HCl, hydrogen fluoride (HF), and sulfur dioxide (SO_2), although they also offer some Hg and PM control. The algorithms used to estimate capital and annual costs of packed bed scrubbers are identical to those used in the 2013 final rule and were originally obtained from Chapter 1 of the CCM.[15] The capital costs comprise the scrubber tower, packing, and pumps. Capital costs are based primarily on inlet gas flowrate and required HCl removal efficiency to reduce the baseline HCl emissions to the targeted MACT floor emission limit. The cost algorithms for estimating capital and annual costs of packed scrubber equipment reduced to their basic equations for each are provided in Appendix D-1. Annual costs include caustic, wastewater disposal, water, electricity, maintenance, labor, capital recovery costs, overhead, administrative, property taxes, and insurance. Appendix D-2 presents the values for the inputs used in this analysis.

3.5 Increased Caustic Rate

Emissions of acid gases such as HCl can be reduced further by increasing the feed rate of lime or sodium bicarbonate ($NaHCO_3$) caustic prior to the fabric filter. Model costs to increase $NaHCO_3$ flow were estimated using similar equations, with a slight difference based on the stoichiometry and molecular weight for $NaHCO_3$. These cost equations are based on the methodology used in the earlier Boiler MACT rulemakings, but the original methodology was established in a memo for Hazardous Waste Incinerators.[16] Updated $NaHCO_3$ costs were obtained to reflect year 2016 costs as shown in Table 1 of this memo in order to estimate the annual cost for increasing the sorbent injection rate. To estimate the increase in the caustic rate, the baseline HCl concentration was compared to the target MACT floor emission rate. Appendix E presents the values for the inputs and the equations used to estimate the annual costs used in this analysis. There are no capital costs associated with this control option, as this incremental control is used in the cost analysis only when units with existing scrubbers or injection

[15] U.S. Environmental Protection Agency, EPA Air Pollution Control Cost manual, Sixth Edition. EPA/452/B-02-001, January 2002. Section 5. Chapter 1. https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution.

[16] Holloway, Thomas. RTI International. Revised Baseline Operating Costs for Existing HMWI Memo. June 19, 2009.

technologies need to increase the efficiency of those systems to meet the MACT floor emission limit.

3.6 Duct Work and Auxiliary Equipment

The algorithms used to estimate capital and annual costs of ductwork were identical to those used in the 2013 final rule and were originally obtained from Section 2 of the CCM.[17] Capital costs include ductwork for any ESP, packed bed scrubber, or fabric filter installed on the unit. The number of duct lines is based on the exhaust flowrate, and it is estimated that 500 feet of duct work is required for every 154,042 acfm of exhaust per control device. The 500 feet of ductwork was based on engineering judgment and previous experience on the distance between emission points and control devices in chemical facilities. Costs are based on ductwork diameter, which is a function of flue gas flowrate. Costs for ductwork also include elbows to connect the duct joints and fans to move the exhaust through the ductwork. The cost algorithms for estimating capital and annual costs for ductwork and auxiliary equipment are included in the individual appendices for Fabric Filters, Packed Bed Scrubbers, and ESP. Annual costs include electricity, maintenance and labor, capital recovery costs, overhead, administrative, property taxes, and insurance.

4.0 Cost Algorithms and Inputs for Monitoring

Some units will require additional monitoring as a result of changes to the control devices installed to meet finalized emission limits. With the exception of carbon monoxide (CO) CEMS and opacity the algorithms used are identical to the ones used in the 2013 final rule aside from updating to year 2016 dollars. The 2013 final rule analysis assumed all units would do CO stack testing since the CO CEMS was an optional limit. For the final rule changes, the EPA has costed out CO CEMS in some cases because it anticipates that some units will opt to used CO CEMS as a result of some of the changes made to the stack test-based emission limits. These monitoring costs were incorporated into the cost estimates, which are discussed in this section.

Monitoring costs are included for opacity monitoring (for units without scrubbers), CO CEMS (for certain units where we anticipate the unit may switch to a CEMS-based emission limit), bag leak detection (for units with fabric filters), scrubber parametric monitoring (for units with scrubbers). Cost estimates for bag leak detection, and wet scrubber parametric monitoring

---

[17] U.S. Environmental Protection Agency, EPA Air Pollution Control Cost manual, Sixth Edition. EPA/452/B-02-001, January 2002. Section 2. https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution

were based on estimates used in the 2009 HMWI rulemaking.[18] CO CEMS and opacity monitor costs were based on the EPA CEMS costing tool.[19] Monitoring costs include the costs for planning, selecting, and installing monitoring equipment and support facilities; conducting an annual relative accuracy test audit and writing the report; performing cylinder gas audits; developing a QA/QC plan; monitoring operations and maintenance; and performing capital recovery. Wet scrubber parametric monitoring was annualized over a 20-year lifetime. Bag leak detection, opacity, and CO CEMS was annualized over a 15-year lifetime. These estimates are consistent with those found in the CCM's monitoring chapter.[20] A summary of the monitoring costs is presented in Appendices G, H, and I.

---

[18] Holloway, Thomas. RTI International, Memo to Mary Johnson, U.S. Environmental Protection Agency, Compliance Costs and Economic Inputs for Existing HMWI. October 24, 2008.

[19] EPA CEMS Cost Model. Research Triangle Institute, 2007, "U.S. EPA Continuous Emission Monitoring System (CEMS) Cost Model." https://www3.epa.gov/ttn/emc/cem/cems.xls

[20] U.S. Environmental Protection Agency, EPA Air Pollution Control Cost manual, Sixth Edition. EPA/452/B-02-001, January 2002. Section 2, Chapter 4. https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution.