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COKE OVEN ENVIRONMENTAL TASK FORCE (COETF)

White Paper - Air Pollution Control Technology Review for Coke Battery Stacks and Pushing Emissions under EPA's Proposed Coke Ovens Risk & Technology Review

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EXECUTIVE SUMMARY

On August 16, 2023, the U.S. Environmental Protection Agency (EPA) proposed revisions to the National Emission Standards for Hazardous Air Pollutants (NESHAP) for the Coke Ovens: Pushing, Quenching, and Battery Stacks (PQBS) source category, 40 CFR 63 Subpart CCCCC, and the NESHAP for the Coke Oven Batteries source category, 40 CFR 63 Subpart L. As part of the proposed Subpart CCCCC rule, EPA proposed new standards for several previously unregulated hazardous air pollutants (HAPs), including new limits for the following HAPs: mercury (Hg), acid gases (AGs) (including hydrochloric acid [HCl] and hydrofluoric acid [HF]), hydrogen cyanide (HCN), and polycyclic aromatic hydrocarbons (PAHs). The proposed rule also includes a proposed particulate matter (PM) limit for Battery Stacks.

The Coke Oven Environmental Task Force (COETF), which represents all four companies that operate byproduct recovery coke plants in the U.S., previously submitted comments setting forth concerns with EPA's proposed rule[1] and also has submitted supplemental comments to EPA regarding an analysis of the lack of achievability of the proposed limits.[2] In summary, the COETF's concerns are that EPA is not required by Clean Air Act section 112(d), or by any mandated interpretation of the *LEAN* decision,[3] to set new "gap filling" standards where, as here:

- Further reductions of the target pollutants are not necessary due to very low risk of the PQBS source category;
- Controlling these pollutants has not been demonstrated for any byproduct recovery coke plant in the U.S. or globally;
- The proposed limits cannot continuously be met without controls (and even considering controls, the proposed limits are not achievable because the target pollutant concentrations are low and beyond the capability of current technology);
- The proposed limits were based on a very limited database of test results that do not account for demonstrated variability in operating conditions, coal blend characteristics, and other factors;
- The cost of adding air pollution controls for Battery Stacks and Pushing Emissions Control (PEC) Systems would be exorbitant and would not be assured of achieving compliance with the proposed limits; and
- The proposed limits are not cost-effective in terms of cost per lb/ton of pollutant reduced due to the extreme cost of controls and the minimal reductions in target pollutants that would be achieved.

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[1] Comments of the Coke Oven Environmental Task Force (COETF) on the Proposed Rule National Emission Standards for Hazardous Air Pollutants for Coke Ovens: Pushing, Quenching, and Battery Stacks, and Coke Oven Batteries; Residual Risk and Technology Review, and Periodic Technology Review (Docket Nos. EPA-HQ-OAR-2002-0085, EPA-HQ-OAR-2003-0051), Oct. 2, 2023.

[2] See the "Compliance Schedule Concerns 020924.pdf" submitted by the COETF to EPA on February 9, 2024. The COETF also has commented separately on EPA's proposed technology review of Subpart L, noting that (i) EPA lacks authority to lower the limits for doors/lids/offtakes because there has not been any development in practices, processes, or control technologies that would authorize a change; and (ii) EPA's proposed limits are based on annual average leak rate data that do not adequately account for shorter-term process, raw material, and seasonal variability. See the "Coke Battery Leak Rates.pdf" submitted to EPA on February 5, 2024.

[3] The COETF's comments note that nothing in the *LEAN* decision alters EPA's obligations under section 112(d) to consider, among other things, costs, non-air quality impacts and achievability, when completing its residual risk and technology review and establishing standards under 112(d). However, when proposing the new standards and gap filling, EPA has not followed Congress' direction as it has failed to appropriately consider such factors.

The COETF's concerns are heightened because there are no air pollution control (APC) technologies currently employed by the industry (or, in some cases, by any other industry), that can achieve the low concentrations of the proposed new HAP limits (i.e., for Hg, AGs, HCN, and PAHs).

Prompted by these concerns, the COETF retained Trinity Consultants (Trinity) to perform an evaluation of the potentially available air pollution control technologies that have either been demonstrated within the byproduct recovery coke industry or that have been demonstrated in other industries to control the proposed target HAPs and to calculate control costs and cost effectiveness values for each potential control technology and target HAP.

As part of this evaluation, Trinity communicated with several technology equipment vendors to identify potential control technologies for Hg, AGs, HCN, and PAHs from Battery Stacks and PEC Systems. Based on the information provided by these vendors, Trinity identified activated carbon injection with fabric filter, and dry sorbent injection with fabric filter as the only technologies potentially feasible for controlling Hg, AGs, and PAHs. No technology was identified that would be feasible to control HCN emissions.

Based on Trinity's experience with the byproduct recovery coke industry and this evaluation of potential APC technologies and costs, coupled with COETF's expertise and input, a significant number of feasibility, engineering, and cost issues were identified. For example, a multipollutant control approach would be required under EPA's proposed rule; however, no single APC technology exists to control all of the target HAPs. As discussed in this paper, control technology for the multiple pollutants proposed in EPA's "beyond the floor" control analysis is not feasible. In addition to multiple pollutant considerations, costs to the industry as a result of the proposed new limits would be exorbitant and unreasonable.

As summarized in Table ES-1 below, the resulting total capital costs for the byproduct recovery coke industry are estimated to be nearly $1.3 Billion, and industry-wide annual costs are estimated to be more than $220 Million/year. These exorbitant control costs result in excessive cost effectiveness values, particularly in light of the minimal HAP reductions that would be achieved. The costs per lb/ton of each target pollutant removed are over $1 Million/ton for AGs from Battery Stacks, over $1.1 Million/lb for Hg from Battery Stacks, and over $193 Million/ton for PAHs from PEC Systems. These cost effectiveness values are drastically higher than those EPA has historically determined to be acceptable.

Table ES-1. Summary of Estimated Control Costs to Byproduct Recovery Coke Industry

Target Pollutant	Source/Control Technology	Industry Total TCI ($)	Industry Total TAC ($)	Industry Total $/lb or $/Ton Removed
Hg	PEC – ACI/Fabric Filter Battery Stacks - ACI/Fabric Filter	643,397,417	111,046,008	1,117,163 ($/lb)
PAHs	PEC – ACI/Fabric Filter	305,355,132	52,315,324	193,359,544 **($/ton)**
AGs	PEC – DSI/Fabric Filter Battery Stack - DSI/Fabric Filter	652,509,917	111,006,874	1,867,859 **($/ton)**
Total Industry Costs		**1,295,907,334**	**222,052,882**	

In conclusion, no control technologies are currently in use within the byproduct recovery coke industry, either in the U.S. or globally, that control emissions of Hg, AGs, HCN, or PAHs from Battery Stacks or PEC Systems. For control systems that theoretically could be used to control these target HAPs, the estimated cost effectiveness of control for the byproduct recovery coke industry would be exorbitant and would far exceed the cost effectiveness for HAP reduction that EPA has historically considered acceptable, particularly given that EPA has determined that risk to public health associated with the entire PQBS source category is low and acceptable and provides an ample margin of safety.

INTRODUCTION

EPA has proposed amendments to the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Coke Ovens: PQBS source category [40 CFR 63 Subpart CCCCC], and the NESHAP for the Coke Oven Batteries source category [40 CFR 63 Subpart L].[4] EPA's proposed rule presents the results of a residual risk and technology review (RTR) for the PQBS source category, and a periodic technology review for the Coke Oven Batteries source category.

In the proposed rule, EPA has determined that risks due to emissions of HAPs from the PQBS source category are acceptable and that the existing PQBS NESHAP protects public health with an ample margin of safety. Under the technology review for the PQBS NESHAP, EPA concluded that there are no developments in practices, processes, or control technologies that necessitate revision of standards for this source category.

However, EPA has proposed new standards for several previously unregulated HAPs for Battery Stacks and PEC Systems, as summarized in Table 1 below.

Table 1. Proposed Standards for Existing Sources

Source or Process	Pollutant	Existing Affected Source Standard	Units for Standard
Pushing	Acid gases (AGs)	0.0052	Lbs/ton coke
Pushing	Hydrogen Cyanide (HCN)	0.011	Lbs/ton coke
Pushing	Mercury (Hg)	8.97E-07	Lbs/ton coke
Pushing	Polycyclic Aromatic Hydrocarbons (PAHs)	3.4E-04	Lbs/ton coke
Battery Stacks	Acid gases (AGs)	0.083	Lbs/ton coke
Battery Stacks	Hydrogen Cyanide (HCN)	0.0039	Lbs/ton coke
Battery Stacks	Mercury (Hg)	5.8E-05	Lbs/ton coke
Battery Stacks	Particulate Matter (PM)	0.10	gr/dscf

Trinity's evaluation confirms EPA's conclusion that there are no identified developments in practices, processes, or control technologies for the PQBS source category.[5] Yet, EPA has proposed new HAP emission standards for Battery Stacks and PEC Systems, despite EPA's determination that the entire PQBS source category presents low and acceptable risk to public health with an ample margin of safety.

EPA's proposed standards for Battery Stacks and PEC Systems were established based on very limited data of emissions stack testing for the byproduct recovery coke industry that are not representative of all such

[4] Federal Register/Vol. 88, No. 157, Page 5585, August 16, 2023/Proposed Rules.

[5] Federal Register/Vol. 88, No. 157, Page 5585, August 16, 2023/Proposed Rules.

coke batteries, the varying composition of raw materials used in these batteries (namely, differing coal blends), and other operational considerations.[6]

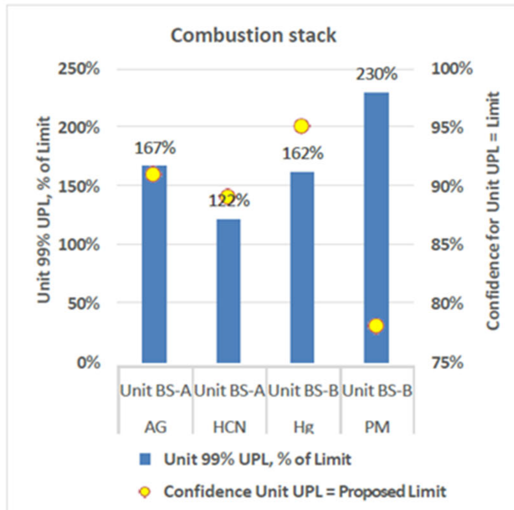
In February 2024, the COETF supplied EPA with a 99% UPL statistical analysis of the limited data used by EPA.[7] That analysis demonstrated that the affected sources (i.e., Battery Stacks and PEC Systems) are incapable of consistently achieving compliance with the proposed standards without the use of air pollution control (APC) technologies or other (unidentified) operational changes. Slide 1 summarizing the UPL statistical analysis is provided below.

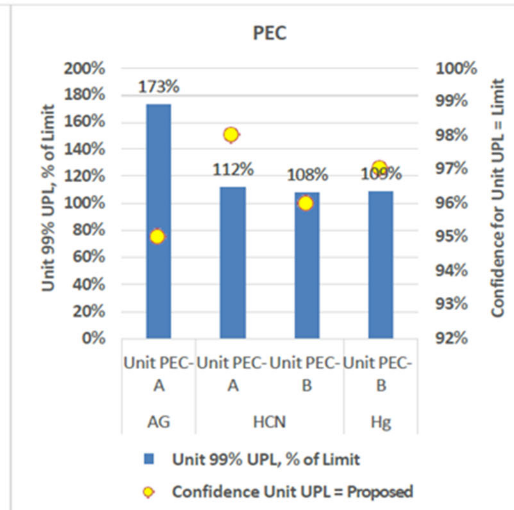
[6] As addressed in comments that the COETF submitted to EPA on October 2, 2023, only 25% of operating by-product coke plants in the U.S. had test data for some subset of the newly proposed limits.

[7] "Compliance Schedule Concerns 020924.pdf" submitted by the COETF to EPA on February 9, 2024.

Compliance Schedule Concerns for Combustion Stacks and Pushing Emissions

- COETF member companies have very little test data regarding the proposed standards for combustion stacks (AGs, HCN, Hg, and PM) and pushing emission control devices (PECs) (AGs, HCN, Hg, and PAH). Only 25% of combustion stacks and PECs were tested as part of the Section 114 ICRs.
- Available data exhibit substantial variability and show that the proposed standards are not consistently achievable for all pollutants without additional controls, operational changes, or both. The figures below show the 99% UPL for individual units (for units with 99% UPL exceeding the proposed standards). The confidence level lower than 99% at which the unit UPL equals the proposed standards also is shown. This analysis shows that additional controls and/or operational changes would be needed for these pollutants/sources:
  - Combustion stacks –
    - PM – New baghouse + fans (depending on PM size fraction)
    - Acid Gases – Dry sorbent injection and new baghouse + fans
    - HCN – No practical controls
    - Hg – Activated carbon injection and new baghouse + fans
  - Pushing –
    - Hg – Activated carbon injection + existing baghouse
    - Acid Gases – Dry sorbent injection + existing baghouse
    - HCN – No practical controls
    - Replacement of existing mobile traveling controls with new fixed controls (baghouse or scrubber) and traveling hood





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To more fully evaluate the potential APC technologies for Battery Stack and PEC System emissions, Trinity examined the feasibility of various APC technologies for the target pollutants and their capital and annual costs. This evaluation focused on technologies specifically targeting control of air emissions from Battery Stacks and PEC Systems for which EPA is proposing new numerical HAP emission limits for byproduct recovery coke plants. A summary of the technical assessment is presented in the Control Technology Review Process section of this paper.

Based on Trinity's experience with byproduct recovery coke plants and air emissions control technologies, together with EPA's assessment of technologies for the coke making industry sector, Trinity concludes that:

- Byproduct recovery coke plants are already using the latest practices and control technologies to minimize emissions from PQBS sources.
- Emissions data used by EPA to support the proposed HAP limits are insufficient to justify any new MACT standards.
- Although no air pollution controls are currently employed in the coke making industry to reduce Hg, AGs, HCN, and PAHs from Battery Stacks or PEC Systems, several potential control technologies exist. Total control costs and cost effectiveness values, in $/ton of pollutant removed, that Trinity generated from cost data obtained for these technologies are dramatically higher than those EPA has historically determined to be acceptable.

In light of these findings, EPA should revise the proposed standards for AGs, PAHs, Hg, HCN, and PM because:

- ► No existing control technologies are utilized at any byproduct recovery coke plants in the U.S. or globally to control the target pollutants from Battery Stacks and PEC Systems.
- ► No other control technologies have been identified that are technically feasible for Battery Stacks and PEC Systems to achieve the proposed standards.
- ► Compliance with the proposed limits cannot continuously be met without controls. However, even considering controls, the proposed limits are not consistently achievable because the target pollutant concentrations are too low for current technology application.
- ► The proposed limits were based on very limited testing data that do not account for demonstrated variability in operating conditions, coal blend characteristics, and other factors.

In the proposed rule, EPA also considered several approaches for employing control technologies for achieving "beyond the floor" levels – that is, determining whether or not more stringent MACT limits should be proposed as standards for certain subcategories in the industry, based on achievability and cost-effectiveness. EPA concluded that there were no cost-effective "beyond the floor" options for byproduct recovery coke plants.

In evaluating technical feasibility and costs for "beyond the floor" levels, EPA evaluated the following technologies:

- Activated Carbon Injection (ACI);
- Wet Alkaline Scrubbing (WAS);
- Regenerative Thermal Oxidation (RTO); and

- Fabric Filter/Baghouse Technologies.

Trinity conducted a similar evaluation, considering numerous potential control technologies aimed at controlling emissions of AGs, PAHs, Hg, and HCN. Tables 2 and 3 below present a summary of control technologies evaluated by Trinity for controlling emissions sufficiently to meet EPA's proposed limits for AGs (HCl and HF), HCN, Hg, and PM for Battery Stacks; and AGs (HCl and HF), HCN, Hg, and total PAHs for PEC Systems, respectively. Cost estimates for evaluated technologies are provided in Appendix A. As presented in these tables, most of the technologies evaluated are not technically feasible for reducing emissions from Battery Stacks and PEC Systems, due to one or more of the following inherent limitations:

- Very low pollutant concentrations within gas streams and constraining available technologies;
- Need for additional equipment (such as a heat exchanger) or complimentary control equipment (such as a second baghouse) with many of the APCs evaluated;
- Physical space limitations within the coke oven battery area; and
- Multipollutant control technology constraints, including equipment limitations and restrictions associated with one pollutant vs. another pollutant (e.g., Hg vs. PAH and AGs vs. SO_2 insofar as their competing for sorbent reactions), and due to Battery Stack and PEC System emissions characteristics and conditions (including pollutant interactions, flow rates, chemistry, and temperatures, and constraining available technologies).

These limitations, along with other control technology considerations, are discussed below.

CONTROL TECHNOLOGY REVIEW PROCESS

To identify potential APC technologies for the evaluation, Trinity first conducted a screening assessment of technologies currently in place at byproduct recovery coke plants globally, as well as in other industry sectors such as utility power generation, steel and ferroalloy manufacturing, and other metals and non-metals industry production processes. The breadth of this screening process targeted control technologies used in cokemaking operations; but, for purposes of potential technology transfer, it looked outside the targeted byproduct recovery coke industry for theoretically compatible APC systems.

To achieve greater consistency in evaluating a large variety of control technologies, Trinity developed "model battery" utilizing actual battery operating data and conditions for Battery Stacks, as well as PEC systems. These parameters for the "model battery" are included in Appendix C. The model battery data were used to evaluate control options based on existing real data.

To compile and consolidate the data, operating conditions from all six currently operating byproduct recovery coke plants were reviewed. Data presented in EPA's coke ovens RTR were included in the data analysis, and basic statistics were applied to the data for the purpose of developing a model battery for obtaining feedback from control technology vendors. Finally, utilizing the available data, averages and means were calculated for exhaust gas flow in dry standard cubic feet per minute (dscfm), temperatures in degrees Fahrenheit (°F), and percent moisture. Similarly, stack test results for target pollutants were evaluated to establish a range of concentrations for PAHs, HCN, Hg, AGs, and PM, as defined in the proposed rule.[8]

Tables 2 and 3 below present the results of the initial control technology identification and screening process for Battery Stacks and PEC Systems, respectively. No such control technologies were found to be utilized at any existing byproduct recovery coke plants either in the U.S. or globally. Trinity then identified candidate controls that showed the best potential for theoretical application to Battery Stack and PEC System emissions. The technologies identified by Trinity for consideration in this screening process included:

- Wet Alkaline (Caustic) Scrubbing;
- Dry Scrubbing with and without Fabric Filtration (e.g., baghouse) and Auxiliary Equipment, such as heat exchangers (HTX);
- Activated Carbon Injection (ACI) with and without Fabric Filtration (e.g., baghouse);
- Wet/Reagent Oil Absorption/Scrubber;
- ACI with Specialty Reagent, with and without Fabric Filtration (e.g., baghouse);
- Fabric Filtration with Thermal Oxidation/Incineration; and
- Carbon Adsorption.

Several control technology vendors (see Appendix B. [Vendor Outreach]) were presented with preliminary concepts for controlling the targeted pollutants from both of the coke plant emission sources being evaluated. The actual "model battery" data in Appendix C, along with the proposed limits for the targeted pollutants, were provided to the vendors. The vendors were asked to provide information on technical

[8] Coke NESHAP Redline Version of Proposed Rule Changes for 40 CFR part 63, subpart CCCCC, July 1, 2023.

feasibility and, if deemed potentially feasible, estimated costs for conceptual pollutant control equipment designs. The conclusions presented in Tables 2 and 3 include consideration of vendor input.

General Limitations and Constraints of the Evaluated Technologies for Controlling Emissions

Technology Limitations and Constraints

Trinity identified several recurring limitations for controlling the targeted pollutants. Notable limitations are discussed below and in later sections of this paper.

Conventional wet scrubbers, such as wet alkaline scrubbers, theoretically can be used for controlling Hg emissions. However, at the very low Hg concentrations and relatively high flow rates present in the exhaust for both source types, this technology will not be effective. A packed-bed type unit would be recommended over a plate/tray tower or spray tower; but, it would have a low capture effectiveness using caustic solution. Vendors were not supportive of using this technology for these exhaust gas streams.

For example, with respect to Hg emissions control, the type (or species) of Hg present in Battery Stack and PEC System emissions is not apparent from testing and public information. Mercury can be either elemental (Hg) or ionic (a.k.a. mercurous) (Hg^+) in nature. The Hg species characterization is important, because it dictates which control technology is more effective -- powdered activated carbon (PAC) or powdered activated carbon with Bromide (or another selected reagent). With respect to carbon or reagent injection technologies, Hg capture occurs primarily within the filter cake dust layer; and the accumulation of mercury at this dust layer is dependent on the Hg species contained in the exhaust gases (i.e., Hg capture efficiency onto activated carbon sites). The removal efficiency (and, therefore, the cost) is greatly related to the dose rate (lb/mmacfm) of carbon and the reagent being used. This presents a significant unknown in the cost evaluation for controlling Hg in either of the target gas streams.

For "acid gases" (AGs), as defined in the proposed rule, control typically is accomplished by reaction with a mineral-based basic reagent (e.g., calcium hydroxide or sodium bicarbonate) through a gas/solid surface reaction. The reaction occurs as the gases and reagent are suspended in-flight between the injection point and a particulate collection device (e.g., fabric filter). The efficiency of the reaction is largely related to the gas temperature, acid gas concentration, and the time of suspension. Sulfur dioxide (SO_2) in the flue gas will also react with the sorbent. The concentration of the target acid gases in a byproduct recovery coke plant's gas stream would be very low and would require a high sorbent-to-acid gas ratio (lb/lb) and a predicted reaction time of greater than 12 seconds. This configuration would require a long reaction time and duct run for effective capture. Due to long residence times, additional equipment would have to be incorporated into existing byproduct recovery coke plant footprints, which are typically very limited in available physical space.

Planning and Engineering Constraints

For any APC system equipment, including any necessary auxiliary equipment, additional cost will be incurred for:

- Redundant equipment (for use during required periodic maintenance or in case of failure), particularly for sources like coke batteries that operate continuously and cannot be idled or taken out of production without risk of significant damage;
- Electrical power supply or transmission limitations, or both; and

- Risk management relative to catastrophic events associated with new equipment or configuration.

For example, the requirement for continuous compliance necessitates the inclusion of redundant equipment to support compliance during planned maintenance of the primary control device, and in case of malfunction or failure of components or equipment. Redundant systems require additional physical space and essentially a doubling of capital investment. In this paper, the costs for purchasing and installing the necessary technical components for redundant systems have been estimated, but not fully addressed; they should be included in final cost evaluations.

Similarly, it will be necessary to assess whether adding an exhaust system or ancillary equipment to a battery will cause catastrophic or other adverse impacts to the heating process, which will affect coke production and, potentially, damage the battery's refractory brick. Indeed, the risk of compromising the integrity of a battery could make any retrofitting for such emission controls infeasible.

Upgrades to electrical power supply may be needed in order to install additional fans and baghouses or other equipment. Depending on site-specific electrical supply requirements, byproduct recovery coke plants may not have enough power to support large fans without an upgrade of the power systems. Addressing any significant electrical supply needs would be a huge undertaking and very expensive. Although cost assumptions were made for electrical supply, specific cost evaluations for any new equipment will require careful planning to obtain costs for implementation. This level of costing was not within the scope of this evaluation.

Finally, costs relative to any lost production have not been incorporated into this evaluation, as they will be driven by the site-specific Battery Stack or PEC System to be controlled, and the length of time that the coke production may need to be idled for installation of controls. Site-specific considerations, including space and electric power constraints, will drive the timeline for such control implications and the resulting costs of lost production.

Table 2. Summary of Battery Stack Control Evaluation Matrix

Pollutant	Air Pollution Control Technologies		Technical feasibility	Technical Feasibility Tier[1,4]	FURTHER ASSESSMENT?
	Control Technology	**Control Technology Description**	**Technical Feasibility and Limitations**	**1, 2, or 3**	**(Yes/ No)**
Acid Gases (HF/HCl)	Wet Caustic Scrubbing	Conventional water-based absorption technology. Process where a soluble pollutant is dissolved into a non-volatile liquid with or without chemical reaction. The rich (i.e., contaminated) stream would be further processed, reused, or treated in a wastewater treatment system or other final destruction method.[2]	Not technically feasible due to low pollutant concentrations, generally less than 250 ppmv.	Tier 3	No
Acid Gases (HF/HCl)	Dry Sorbent (DS) Injection (e.g., Dry Scrubbing) and Fabric Filter (FF) and HTX)	Inject dry, alkaline or other selected chemical sorbent into flue gas, upstream of fabric filter. Dry sorbent injection avoids potential wet scrubbing issues, including wastewater treatment, corrosion and steam plume problems, and delivery nozzle plugging (spray dryer absorption). DS/FF has more efficient sorbent utilization, relative simplicity, and a small footprint.	Technology will require FF and heat exchanger, but is feasible. Relative to sorbent reaction time, distance between injection point and fabric filter will determine control efficiency. A circulating sorbent reactor (CSR) could potentially be used to increase removal efficiency if space permits. Related technologies include spray dryer absorption, wet scrubbers, and furnace sorbent injection.	Tier 2	Yes
HCN, Mercury, and PM	Activated Carbon and Fabric Filter (baghouse)	Conventional application of a baghouse with activated carbon injection (ACI) upstream of baghouse. Fabric filter to allow desired reaction within dust layer.	Design and ducting configuration of the new baghouse will need to be developed. To help capture HCN, a special reagent (i.e., metalized carbon, bromide) may be needed. SO_2 interferes with HCN capture and control, requiring desulfurized coke oven gas (COG); units with undesulfurized COG will require either additional operating cost (for reagent), or additional sulfur control or both.	Tier 3	No
HCN, Mercury, and PM	Reagent-specific (Bromide) Activated Carbon and Fabric Filter (baghouse)	Fabric filter and ACI with special brominated reagent to efficiently capture mercury, HCN, and PAHs. Fabric filter to allow desired reaction within dust layer.	Bromide target reagent; but other metals possible, just not commercially available. Bromide has the potential for higher removal efficiency than traditional injection. SO_2 interferes with HCN capture and control, requiring desulfurized coke oven gas (COG); units with undesulfurized COG will require either additional operating cost (for reagent), additional sulfur control, or both.	Tier 3 (HCN) Tier 2 (Others)	Yes
HCN, Mercury, and PM	Fabric Filter (baghouse) and Thermal Oxidation/Incineration	Application of a baghouse with a subsequent incineration device; thermal destruction for HCN will be post PM removal.	Due to Hg concentrations generally below 100 ppb, the removal efficiency of mercury expected to be low. The high flow rate and low concentration makes the destruction of HCN by incineration impractical. SO_2 interferes with HCN capture and control, requiring desulfurized coke oven gas (COG); units with undesulfurized COG will require either additional operating cost (for reagent), additional sulfur control or both.	Tier 3	No
PM	Fabric Filter (baghouse)[5]	Application of traditional baghouse/fabric filter technology.	Technically feasible in theory; however, the technology would need to be combined with other APC technologies to address other pollutants of concern.	Tier 2	Yes
Mercury	Fixed Carbon Bed/ Regenerative Carbon Bed	Using the adsorption process, gaseous pollutants are removed from an air stream by transferring the pollutants to the solid surface of an adsorbent, usually activated carbon. Other commonly used adsorbents include zeolites and polymers. Adsorbents typically are regenerated (desorbed/removed) either off-site or on-site.	Requires significant space for carbon beds and regeneration process, given the flow rates in question. Saturation capacity (the maximum capacity the adsorbent can hold) and breakthrough capacity (the amount of pollutant that can be adsorbed before a significant pollutant concentration exits or breaks through the bed) must be determined for relevant pollutants.	Tier 3	No[3]
Mercury	Fabric Filter Carbon-embedded Bags	Hg captured by carbon embedded in fabric structure and bags replaced when break through occurs.	Can be included in baghouse filter design; will inherently reduce PM (and other pollutants to a lesser degree. including acid gases (chlorides/fluorides) and HCN, depending on chemistries).	Tier 3	No

NOTES:
1. Technical Feasibility Tier, where: Tier 1 [Technically Feasible and Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally]; Tier 2 [Potentially Technically Feasible but Not Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally]; and Tier 3 [Technically Not Feasible and Not Demonstrated Anywhere in the U.S. or Globally].
2. EPA-450/2-77-019, Sept. 1977. EPA Guideline Series, control of sulfuric acid mist emissions from existing sulfuric acid production units.
3. Trinity contacted several vendors regarding this technology, including those specializing in carbon adsorption technology. Also, other vendors tried to gain insights into the technology's viability for these pollutants and from these exhaust streams. These efforts have not identified compatible carbon adsorption technology.
4. Concerns identified during site-specific engineering may result in certain technologies being determined technically infeasible (Tier 3), rather than potentially technically feasible (Tier 2). Some of these potential concerns are noted in this paper.
5. PM particle sizes less than 1 µm might be captured with wet ESP technology. However, this technology is less practical in any other circumstance and was not considered further in this evaluation.

Table 3. Summary of Pushing Emissions Control System Control Evaluation Matrix

Pollutant	Air Pollution Control Technologies: Control Technology	Control Technology Description	Technical feasibility: Technical Feasibility and Limitations	Technical Feasibility Tier[1,5]: 1, 2, or 3	Further Assessment?: (Yes/ No)
Acid Gases (HF/HCl)	Wet Scrubbing	Conventional water-based absorption technology.	Not technically feasible due to low pollutant concentrations generally less than 100 ppmv. Multiple reaction vessels required and would not be practical.	Tier 3	No
Acid Gases (HF/HCl)	Dry Sorbent Injection (i.e., Dry Scrubbing (DS) and Existing Fabric Filter (FF))[4]	Inject a dry, alkaline or other selected chemical sorbent into flue gas, upstream of fabric filter. Dry sorbent injection avoids potential wet scrubbing issues, including wastewater treatment, corrosion and steam plume problems, and delivery nozzle plugging (spray dryer absorption). DS/FF has more efficient sorbent utilization, relative simplicity, and a small footprint.	Technology is feasible. Relative to sorbent reaction time, distance between injection point and fabric filter will determine control efficiency. A circulating sorbent reactor (CSR) could potentially be used to increase removal efficiency if space permits (compatible with capture systems utilized by four COETF member company plants).	Tier 2	Yes
HCN, Mercury, and PAHs	Activated Carbon and Existing Fabric Filter (baghouse)[4]	Conventional application of a baghouse with activated carbon injection (ACI) upstream of baghouse. Fabric filter to allow desired reaction within dust layer.	The air:cloth ratio on existing baghouse may not be sufficient. To help capture HCN, selective reagent (i.e., metalized carbon, bromide) may be needed. SO_2 interferes with HCN capture and control – requires desulfurized coke oven gas (COG); units with undesulfurized COG will require additional operating cost (for reagent) and/or additional sulfur control.	Tier 3 (HCN) Tier 2 (Others)	Yes
HCN, Mercury, and PAHs	Reagent-specific (Bromide) Activated Carbon and Existing Fabric Filter (baghouse)[4]	Fabric filter and ACI with special metalized reagent (e.g., bromide) to efficiently capture mercury, HCN, and PAHs. Fabric filter to allow desired reaction within dust layer.	The air:cloth ratio on existing baghouse may not be sufficient. Mercury species will dictate whether a conventional ACI or reagent (e.g., bromide) system will be required. This technology will not work with coke plants lacking a desulfurization process. SO_2 interferes with HCN capture and control – requires desulfurized coke oven gas (COG); units with undesulfurized COG will require additional operating cost (for reagent) and/or additional sulfur control.	Tier 3 (HCN) Tier 2 (Others)	Yes
HCN and PAHs	Thermal Oxidation (TO)/Incineration	TO/incineration would be situated post existing fabric filter (assuming HCN and PAHs not controlled with ACI system).	The low sensible heat of exhaust will require substantial natural gas to combust HCN and PAHs. Will likely substantially increase CO_2.	Tier 3	No
PAHs	Wet Oil/Reagent Scrubbing	Conventional oil-based absorption technology. Soluble pollutant is dissolved into scrubbant (oil wash). The rich (i.e., contaminated) stream would be further processed, reused, or treated in a wastewater treatment system or sent offsite for destruction/disposal.	Not feasible for low concentrations and multi-pollutant control systems.	Tier 2	No
Mercury	Fixed Carbon Bed after Existing Fabric Filter[4]	Using the adsorption process, gaseous pollutants are removed from an air stream by transferring the pollutants to the solid surface of an adsorbent, usually activated carbon. Other commonly used adsorbents include zeolites and polymers. Adsorbents typically are regenerated (desorbed/removed) either off-site or on-site.	Requires significant space for carbon beds. Saturation capacity (the maximum capacity the adsorbent can hold) and breakthrough capacity (the amount of pollutant that can be adsorbed before a significant pollutant concentration exits or breaks through the bed) must be determined for relevant pollutants.	Tier 3	No[3]
Mercury	Regenerative Carbon Bed after Existing Fabric Filter[4]	Adsorption technology with activated carbon or other media that can be regenerated/reactivated onsite with steam or chemical treatment.	Requires significant space for carbon beds and regeneration process equipment, given the flowrates in question. Saturation capacity (the maximum capacity the adsorbent can hold) and breakthrough capacity (the amount of pollutant that can be adsorbed before a significant pollutant concentration exits or breaks through the bed) must be determined for relevant pollutants.	Tier 3	No[3]
Mercury & PAHs	Fabric Filter Carbon-embedded Bags after Existing Fabric Filter[4]	Hg captured by carbon embedded in fabric structure. Bags replaced when breakthrough occurs.	Commercial use appears rare or non-existent. Retrofit alternatives need further evaluation. Has potential to enhance multipollutant control, including PM and other pollutants. Research[2] addresses all EPA-proposed PAHs except perylene, but does include Benzo(g,h,i) perylene.	Tier 3	No

NOTES:
1. Technical Feasibility Tier, where: Tier 1 [Technically Feasible and Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally]; Tier 2 [Potentially Technically Feasible but Not Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally]; and Tier 3 [Technically Not Feasible and Not Demonstrated Anywhere in the U.S. or Globally].
2. SZhen-Shu Llu, Journal of Environmental Engineering, May 2006.
3. Trinity contacted vendors regarding this technology, including those specializing in carbon adsorption technology. Also, other vendors tried to gain insights into the technology's viability for these pollutants and from these exhaust streams. These efforts have not identified compatible carbon adsorption technology.
4. At least one byproduct recovery coke plant does not have an existing baghouse for its PEC System and would require a new movable hood, ductwork, baghouse and related high voltage power line and substation for new equipment.
5. Concerns identified during site-specific engineering may result in certain technologies being technically infeasible (Tier 3) rather than potentially technically feasible (Tier 2). Some of these potential concerns are noted in this paper.

CONTROL TECHNOLOGY REVIEW – BATTERY STACK EMISSIONS

In assessing a control strategy for Battery Stack emissions, Trinity performed additional evaluation of the Tier 2 technologies (Potentially Technically Feasible but Not Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally) presented in Table 2, including:

- Activated Carbon Injection (ACI) with Reagent-specific addition combined with Fabric Filter (for Hg and PM); and
- Dry Sorbent Injection (DSI) combined with Fabric Filter (for AGs [HCl] and PM).

An application evaluation of the technologies was considered by vendors, and preliminary control technology designs and configurations were developed based on the above discussed model battery and proposed emissions limits. Costs for these preliminary designs/configurations were developed based on equipment vendor data, EPA cost estimating techniques, and general APC technology concepts.

Regarding the dry scrubbing technologies (i.e., DSI), challenges associated with controlling AGs from Battery Stacks include:

- Due to the required long reaction time between sorbent and pollutants, a recirculating sorbent reactor vessel would be required between the injection point and fabric filter to increase time for reaction; this would overcome the poor removal efficiency. This approach would have physical space constraints.
- Physical space available near most Battery Stacks is limited such that placement of a control system (such as injectors, fabric filter, ID fan, and stack) would be problematic.

Technical and Economic Considerations for Battery Stacks

Controlling emissions from Battery Stacks presents several physical and control chemistry challenges which limit the ability to implement controls. The general design of battery underfire combustion systems include coke oven gas (COG) burners for individual ovens and regenerative heat exchangers (i.e., "checkers") for flue gas heat recovery and preheating of combustion air. After heat recovery, the flue gases are directed to waste gas collection mains and pass underground through a refractory-lined duct to the Battery Stack. The gases are then exhausted by natural draft suction to the Battery Stack. Because the existing waste gas duct at all byproduct recovery coke plants is located underground, the gases would need to be diverted to an above-ground abatement system for connection, which would require a scheduled battery outage for construction and tie-in of the diversion. During the outage, most batteries will need to purchase natural gas to keep the battery hot (cost for this is not included in this study); all coke production would cease; and battery refractory brick and other equipment could suffer unanticipated damage, the repairing of which would add expense. The costs of any repairs and lost production are not included in EPA's evaluation.

Adding equipment such as sorbent injection systems, fabric filtration, and heat exchangers (HEX) would interrupt this balance by adding static pressure loss, necessitating use of an induced draft (ID) fan to overcome the increased static pressure loss. The impacts of added fans and equipment require more study beyond this evaluation to ensure adequate heating of the batteries and enough physical space to install additional equipment. Finally, to accommodate equipment to address the natural draft exhaust and route the stream through new APC(s), a new Battery Stack likely will be needed after these new gas cleaning steps.

In summary, the challenges associated with controlling emissions from Battery Stacks include:

1) Physical redesign of the battery underfire combustion heating system and waste gas ducting, which would require installation of an ID fan;
2) Battery outage for construction and tie-in;
3) Construction or modification of Battery Stacks;
4) Challenges of adding APCs to existing equipment; the byproduct recovery coke industry has never attempted to add the APCs in question (EPA addressed this in its assumptions using a severely understated retrofit cost factor);
5) Potential need for expanded or upgraded electrical power supply;
6) Costs and space constraints for redundant systems to continuously meet emission limits; and
7) Costs to repair any damage to refractory brick and other equipment that occur as a result of any battery outage.

Based on the limited data available (which are discussed in previous COETF comments on the proposed rule),[9] the fact that none of these controls have been demonstrated in the byproduct recovery coke industry (either domestically or globally), and the low concentrations of pollutants that will have to be removed, it is likely that any selected APC system will fail to achieve the desired destruction or removal efficiency and continually achieve the levels in the proposed rule (see Table 1).

In evaluating the technical feasibility and cost estimates across the byproduct recovery coke industry, Trinity considered the following elements for a "model" Battery Stack to normalize the emissions from the various Battery Stacks:

- Underfire heat input and coke oven gas (COG) heat value that are oven-specific (i.e., based on the number and size of ovens, and COG's higher heating value); and
- For the "model" Battery Stack, the number of ovens, coal charge/oven ratios, rates of coke produced per oven, COG generation rates (cubic feet/ton coal charge or coke produced), and the percentage of COG fired in the underfire heating system.

These elements, together with the technical challenges described above, result in significant uncertainties in APC technology efficiencies. The issues related to controlling the target emissions are further complicated by multipollutant control challenges. No single APC technology is able to control all the targeted pollutants covered by the proposed rule.

Along with the technical challenges of new APC technologies and auxiliary equipment, the available physical space at existing byproduct recovery coke plants is very limited. Depending on the equipment configurations and layouts at existing plants, additional engineering and planning are crucial to overcoming the physical space limitations associated with the placement of any new APC device and auxiliary equipment. As a general matter, all the above factors will likely result in costs higher than those presented in Table 4, which are already more than those estimated by EPA.

[9] An equipment redundancy cost of 50% was applied to the capital investment figures to account for redundant components.

Control Cost Estimation Approach

Trinity reviewed all of the control cost estimates for existing sources that EPA provided as part of the rulemaking docket. Trinity utilized information in document EPA-HQ-OAR-2002-0085-0859_attachment_6.xlsx to supplement vendor supplied information and cost data and to serve as the starting point for the evaluation. Using the general approach contained in EPA-HQ-OAR-2002-0085-0859_attachment_6.xlsx ensured a consistent approach, where possible, to that used by EPA with respect to control cost estimating methods as well as assumed pre- and post-control emission rates. The resulting cost estimates and cost effectiveness calculations are presented in Appendix A and summarized in Table 4 below. Key differences between Trinity's methods and those presented by EPA in the proposed rule include the following:

- ACI
  - Trinity's analysis used updated 2024 total capital investment (TCI) based on a preliminary budget estimate provided by a vendor.
  - Trinity applied a redundancy cost of 50% to the capital investment figures to account for redundant components.
  - Trinity updated the exhaust gas flow rate to only include the average for byproduct recovery coke batteries that are still in operation.
  - Trinity updated the ACI injection rate to approximately 6 lb/mmacf based on an updated study by Sargent & Lundy.[10] The derivation of this injection rate is included in Appendix A and is based on heat input data from 2016 ICR testing conducted by one byproduct recovery coke plant on its Battery Stack. This impacts the Total Annual Cost (TAC), which includes use of EPA's approach for capital recovery considering equipment life and interest rates. Trinity's analysis retained EPA's assumptions for equipment life and interest rates.
- DSI
  - Trinity added calculations in lieu of the use of a wet scrubber (EPA's assumed control) for the reasons noted in Table 2 above.
  - Trinity used cost methodology similar to that used for ACI, with the exception of TCI and sorbent costs.
  - Considering that AG reductions using DSI are highly variable (particularly in exhaust streams with SO_2), Trinity assumed 90% control, given uncertainties regarding application of this technology to the byproduct recovery coke industry.
  - Trinity assumed that TCI was based on a budget estimate provided by a vendor in 2024.
  - A redundancy cost of 50% was applied to the capital investment figures to account for redundant components.
  - Trinity assumed a sorbent injection rate based on a formula contained in the Portland Cement NESHAP docket (in document EPA-HQ-OAR-2002-0051). SO_2 can compete for agent reaction, thus lowering the effectiveness of AG controls without increased injection. The resulting increased injection rate would also substantially increase annual operating costs. This limitation is amplified for any byproduct recovery coke batteries without desulfurization.

[10] IPM Model - Revisions to Cost and Performance for APC Technologies, Mercury Control Cost Development Methodology Final, Sargent & Lundy, LLC; March 2023

As such, two annual operating costs were developed: one for a Battery Stack at a site with an existing desulfurization system; and one at a site without an existing desulfurization system. For the desulfurization scenario, SO_2 emissions for this equation were based on the average Battery Stack emissions for calendar year 2020 operations at the Monessen (PA) and Clairton (PA) byproduct recovery coke plants (i.e., based on readily available data). For the scenario without desulfurization, actual emissions from the Burns Harbor (IN) Plant were used for the SO_2 emissions in the equation.

- Fabric Filter
    - Trinity determined that a fabric filter was the most likely candidate control technology, whereas EPA did not assume an additional PM control device was needed for Battery Stacks.
    - Trinity computed capital costs for a new baghouse based on https://www.epa.gov/system/files/documents/2021-09/attachment_5-7_pm_control_cost_development_methodology.pdf.[11]
    - Trinity applied a redundancy cost of 25% to the capital investment figures to account for redundant components (fans, oversizing of compartments, etc.).
    - Trinity utilized operating costs for a fabric filter based on EPA's baghouse cost template in Attachment 5 referenced above (cost for electricity and air excluded for simplicity).
- Ductwork
    - Trinity used EPA's cost for ductwork; however, EPA's costs are severely understated. The cost for ductwork will increase due to the complexities of retrofitting or installing a control device or auxiliary equipment (such as a heat exchanger) in the space-constrained area of byproduct recovery coke batteries.
- "Cost of Controls" Summary Table
    - Baseline emissions for cost effectiveness calculations are those taken from EPA's control costs evaluation (EPA-HQ-OAR-2002-0085-0859_attachment_6.xlsx).
    - Additional costs for retrofitting were not included due to the need for further site-specific evaluations. These costs include, but are not limited to, costs for heat exchangers to reduce the temperature to the desired inlet temperature; significant costs associated with battery outages, including natural gas needed to keep the battery hot; costs for new or modified Battery Stacks; and costs for potential vertical construction or relocation of other assets. The cost for a new Battery Stack was included, based on readily available information for replacing a Battery Stack at one existing coke plant.
    - There will be a need for redundant equipment (i.e., key portions of the emission control system) to continuously comply with the limits. The costs for these redundant systems are addressed, to the extent possible, as noted above.
    - Trinity utilized a retrofit factor of 1.25, consistent with EPA's control cost calculations for ductwork. But, the actual retrofit factor, while undefined now, would be much greater than 1.25 due to space constraints, costs due to loss of production, and other factors.
    - Based on vendor-supplied information, Trinity determined that HCN control was not available or quantifiable.

[11] IPM Model – Updates to Cost and Performance for APC Technologies, Particulate Control Cost Development Methodology Final, Sargent & Lundy, LLC; April 2017

- Byproduct recovery coke batteries that have been permanently closed were removed from the cost evaluations. These include batteries in Follansbee, WV; Middletown, OH; Birmingham, AL (Bluestone Coke); and Clairton, PA (Batteries 1-3).
- Costs and technologies were updated per the Trinity assessment. Given the assumptions made in these revised control costs calculations, and significant technical impediments not included due to the site-specific engineering necessary to adequately address them, the costs presented are conservatively low.

Table 4. Battery Stack Control Options Summary (Cost Per Application)[12]

Technology	TCI Est.* (EPA)	TAC Est.* (EPA)	TCI Est.* (Trinity)**	TAC Est.* (Trinity)	Target Pollutants
ACI with Fabric Filter and New Stack	$81,498	$167,201	$22,536,152	$3,915,379	Hg
DSI with Fabric Filter and New Stack (Sites with Desulfurization)	Not evaluated	Not evaluated	$22,873,652	$3,701,624	AGs
DSI with Fabric Filter and New Stack (Sites without Desulfurization)[13]	Not evaluated	Not evaluated	$22,873,652	$5,044,042	AGs

*TCI = Total Capital Investment; TAC = Total Annual Cost
**Cost includes conservatively low assumptions for redundancy (50% for ACI and DSI; 25% for fabric filter).

[12] Costs are understated based on the technical concerns discussed in this evaluation (e.g., battery idling, space constraints, rerouting of combustion exhaust, etc.). Trinity applied a retrofit factor of 1.25 consistent with EPA's value for duct work. Once site-specific engineering is conducted, it is possible that certain technologies may be infeasible.

[13] Total Annualized Costs for certain technologies (i.e., ACI and DSI) may have substantial additional operating costs. These costs are further complicated by the potential interference caused by SO_2 in the exhaust stream. DSI costs have been estimates for coke plants with and without desulfurization systems. It is possible that a desulfurization unit may be necessary for the injection system to achieve the proposed standards. This cost is not included in this evaluation.

CONTROL TECHNOLOGY REVIEW – PUSHING EMISSIONS CONTROL SYSTEMS

As with the evaluation of APC technologies for Battery Stack emissions, Trinity performed an assessment of the Tier 2 technologies (Potentially Technically Feasible but Not Demonstrated within Byproduct Recovery Coke Industry in the U.S. or Globally) for PEC Systems as presented in Table 3, including:

- Activated Carbon Injection (ACI) with and without Reagent-Specific Addition, combined with Fabric Filter (for Hg, PAHs); and
- DSI combined with Fabric Filter (for AGs).

Trinity assessed preliminary control technology designs and configurations for these technologies. Capital and operating costs for these preliminary designs were developed based on equipment vendor data, EPA cost estimating techniques, and general APC technology concepts.

Technical and Economic Considerations for PEC Systems

Controlling emissions from PEC Systems presents physical and control chemistry challenges similar to those for Battery Stack emissions. With one exception, the general design of PEC Systems at existing byproduct recovery coke plants relies on pushing emissions capture-and-control via a fabric filter baghouse. While the end-of-pipe control device is similar (that is, a baghouse), there are several different types of emissions capture devices in use, as indicated below. The one exception to the PEC System baghouse is a byproduct recovery coke plant that uses a mobile scrubber car system.

For PEC Systems that currently use a fabric filter baghouse to control pushing emissions, the four types of systems include:

1) Moveable hood, belt sealed duct (to fabric filter);
2) Moveable hood, dampered ports (to fabric filter);
3) Stationary shed (to fabric filter); and
4) Enclosed coke guide and scrubber car (not included in this evaluation).

Based on this evaluation, it is acknowledged that existing control systems may not be adequate to address the additional loading from proposed injection systems. As such, Table 5 costs account for installation of a new fabric filter system at each site. The costs presented reflect a "model" PEC System at a byproduct recovery coke plant.

Control Cost Estimation Approach

Similar to the analysis performed for Battery Stacks, Trinity reviewed existing control cost estimates provided by EPA as part of the rulemaking docket. Trinity referenced document EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx to supplement vendor supplied information and cost data, and to serve as the starting point for the updated evaluation. The resulting cost estimates and cost effectiveness calculations are presented in Appendix A and summarized in Table 5. Key differences between Trinity's methods and those in the proposed rule include the following:

- ACI
  - Trinity updated the 2024 TCI based on a preliminary budget estimate provided by a vendor.
  - Trinity applied a redundancy cost of 50% to the capital investment figures to account for redundant components.
  - Trinity updated the exhaust gas flowrate to only consider the average for the byproduct recovery coke batteries that are still in operation.
  - Trinity updated the ACI injection rate to 6 lb/mmacf. Based on similar flowrates and small concentration loading, this value was retained from the Battery Stacks analysis.
- DSI
  - Trinity added these calculations in lieu of assuming the use of a wet alkaline scrubber (EPA's assumed control) for the reasons noted in Table 3.
  - Trinity used a cost methodology similar to that used for ACI, with the exception of TCI and sorbent costs.
  - Because AG reductions using DSI are highly variable, Trinity assumed 90% control, given the uncertainties regarding application of this technology to the byproduct recovery coke industry.
  - Trinity used a 2024 TCI based on a budget estimate provided by a vendor.
  - Trinity applied a redundancy cost of 50% to the capital investment figures to account for redundant components.
  - Trinity used a sorbent injection rate based on a formula included in the Portland Cement NESHAP docket (in document EPA-HQ-OAR-2002-0051). SO_2 emissions for this equation were based on the average PEC System emissions for calendar year 2020 operations at the Monessen (PA) and Clairton (PA) byproduct recovery coke plants (i.e., from readily available data).
- Fabric Filter
  - Trinity assumed that each byproduct recovery coke plant will need to include a new fabric filter.
  - Capital costs are based on estimates for application of new technology to the Warren (OH) plant's PEC system.
  - The costs for electricity and air were excluded from total annual costs for simplicity.
- Ductwork
  - Trinity used EPA's cost for ductwork, but that cost is significantly understated (as noted previously).
- "Cost of Controls" Summary Table
  - Baseline emissions for cost effectiveness are those taken from EPA's control costs evaluation (EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx).
  - Additional costs for retrofitting, for known engineering considerations that were not included due to the need for further site-specific evaluations, include, but are not limited to: heat exchangers to increase temperature to the desired inlet temperature; and potential vertical construction or relocation of other assets.

- Trinity utilized a retrofit factor of 1.25, consistent with EPA's control cost calculations for ductwork. The actual retrofit factor, while not estimated in this paper, would be significantly greater than 1.25 due to space constraints, costs due to loss of production, etc.
- Based on vendor discussions, HCN control was determined not to be available or quantifiable.
- There will be a need for redundant equipment (i.e., key portions of the emission control system) to continuously comply with the limits. The costs for these redundant systems are addressed, to the extent possible, as noted above.
- Byproduct recovery coke batteries that have been permanently closed were removed from the cost evaluations. These include batteries in Follansbee, WV; Middletown, OH; Birmingham, AL (Bluestone Coke); and Clairton, PA (Batteries 1-3).
- Costs and technologies were updated per the Trinity assessment. Given the assumptions made in these revised control cost calculations, and significant technical impediments not included due to the site-specific engineering necessary to adequately address them, the costs presented are conservatively low.

Table 5. PEC Systems with Existing Baghouse Options Summary (Cost Per Application)[14]

Technology	TCI Est.* (EPA)	TAC Est.* (EPA)[15]	TCI Est.* (Trinity)**	TAC Est.* (Trinity)	Target Pollutants
ACI with New Fabric Filter	Not evaluated	Not evaluated	25,446,261	4,359,610	Hg, PAHs
DSI with New Fabric Filter[13]	Not evaluated	Not evaluated	25,783,761	4,064,202	AGs

*TCI = Total Capital Investment; TAC = Total Annual Cost
**Cost includes conservatively low assumptions for redundancy (50% for ACI and DSI).

[14] Costs are understated based on the technical concerns discussed in this analysis (e.g., space constraints). Trinity applied a retrofit factor of 1.25 consistent with EPA's value for duct work. Once site-specific engineering is conducted, certain technologies may be infeasible.

[15] Total Annualized Costs for certain technologies (i.e., ACI and DSI) may have substantial operating costs. These costs are further complicated by the potential interference caused by SO_2 in the exhaust stream.

CONCLUSIONS

Trinity evaluated several potential APC systems to control emissions from Battery Stacks and PEC Systems, as presented in Tables 2 and 3. Table 6 below summarizes the estimated costs for several APC systems that were selected for further evaluation, including a technical and economic feasibility review, with technology vendors. The potential APC systems selected for further evaluation, and some of the technical (and schedule) concerns with them, were summarized in "Compliance Schedule Concerns" comments that the COETF provided to EPA on February 9, 2024.[16]

In an effort to obtain realistic input on APC technology applications and associated costs, Trinity obtained information from several APC technology vendors and reached the following conclusions:

1) None of the identified APC technologies are currently demonstrated in the byproduct recovery coke industry, either in the U.S. or globally.
2) Wet alkaline scrubbers cannot adequately address AGs, considering the low exhaust stream concentrations with high exhaust flow rates common with these streams.
3) Due to equipment configurations and layouts at existing coke plants, additional engineering and planning will be crucial to overcoming limitations of physical space associated with the placement of any new APC device and auxiliary equipment.
4) Significant challenges exist with respect to control of Battery Stack emissions, including the need to perform a planned battery outage and address the natural draft nature of the under-firing system. The necessary retrofitting could have a catastrophic impact on coke production or the battery itself. Such costs and long-term implications are not addressed in this paper.
5) The proposed PM grain loading requirement for Battery Stacks can likely be met with conventional fabric filter (baghouse) technology if the PM particle size is greater than approximately one micron (>1 µm) aerodynamic diameter. However, there are significant doubts that such a technology can be used effectively in controlling PM particles less than 1 µm in diameter.
6) As demonstrated by other industries, Hg can be captured using ACI or DSI technologies. However, the reduction efficiency is difficult to predict for byproduct recovery coke plant operations due to plant-specific conditions and emissions characteristics (including low concentrations and the type or form of mercury present).
7) No technology was identified that would be feasible to control HCN emissions.
8) The control of AGs is theoretically feasible in a DSI using hydrated lime, sodium bicarbonate, or other reagents. However, Battery Stack and PEC System emissions potentially include other acid gases, such as SO_2. SO_2 in the gas stream will compete for reagent reaction and will lower the conversion/destruction of AGs. This complication makes the evaluation very difficult and complex because auxiliary equipment such as Reaction Towers, reagent storage silos, and large vertical duct runs to allow for sufficient reaction time, will be necessary. The need for such auxiliary equipment will necessitate significant site-specific engineering studies and, likely, the need for large available footprints at space-constrained byproduct recovery coke plants. In the Battery Stack scenario, SO_2 will compete for reagent targeted toward HCl and HF. The resulting increased injection rate would

[16] "Compliance Schedule Concerns 020924.pdf" submitted by the COETF to EPA on February 9, 2024.

also substantially increase annual operating costs. This limitation is amplified for any batteries that do not include desulfurization.

As discussed above, based on Trinity's expertise and research, together with information provided by APC vendors, no viable technologies existing for controlling the targeted pollutants from byproduct recovery coke plants. EPA's evaluation of potential controls for Hg at these plants did not consider the additional technologies that would be required (e.g., baghouses with ACI for Hg control and heat exchangers to optimize gas stream temperatures for effective control). In sum, there are no technologies available that would control all the proposed pollutants in each of the two exhaust gas streams (from Battery Stacks and PEC Systems).

Vendor cost data relative to the model coke plant specifications developed by Trinity are very limited. Trinity developed cost estimates for certain technologies using available public data and cost estimating tools. These cost estimates are significantly higher than those estimated in EPA's proposed rule. As indicated in Table 6, EPA's estimates grossly understate the actual costs of retrofitting these APC technologies.

While APC technologies exist that address certain targeted pollutants, there is no single technology that addresses all of these pollutants in combination. Furthermore, with respect to potentially feasible APCs, we found no evidence of any byproduct recovery coke plants using these technologies to control Battery Stack or PEC System emissions. Indeed, site-specific engineering evaluations, which have not been conducted by EPA, would be needed to design and estimate the cost of *potentially* effective APCs. Trinity applied a conservative retrofit cost factor of 1.25 to account for some of this uncertainty.

Furthermore, it is unlikely that the byproduct recovery coke industry could consistently achieve compliance with the proposed standards, and any APCs would not be effective in achieving the proposed standards as supported by this evaluation. Along with ineffective pollutant removal efficiencies, total control costs to industry associated with the evaluated APC technologies and cost effectiveness values are extremely high as summarized in Table 6 and Appendix A.

Industry-wide total capital costs are estimated to be nearly $1.3 Billion, and industry-wide annual costs are estimated to be over $220 Million/year. The resulting cost effectiveness values are over $1 Million/ton for AGs from Battery Stacks, over $1.1 Million/lb for Hg from Battery Stacks, and over $193 Million/ton for PAHs from PEC Systems. These cost effectiveness values are dramatically higher than those EPA has historically determined to be acceptable. The high financial investments reflected in this paper are not acceptable, particularly given that EPA has already determined that risk to public health associated with the entire PQBS source category is low and acceptable and provides an ample margin of safety.

Finally, in light of the numerous technical limitations for controlling the target pollutants at these sources, the costs detailed below are likely to be significantly understated.

Table 6. Summary of Estimated Control Costs to Byproduct Recovery Coke Industry[17]

Source or Process	Target Pollutant	Control Technology	TCI per Emissions Source ($)*	TAC per Emission Source ($)*	No. of Industry Sources	Industry TCI ($)*	Industry TAC ($)*	Industry Total Pollutant Reductions per EPA Baseline (tpy)[18]	Industry Total $/lb or $/Ton Removed
PEC with New Fabric Filter	Hg	ACI + Fabric Filter	25,446,261	4,359,610	12	305,355,132	52,315,324	0.0007	**35,710,236 ($/lb)**
PEC with New Fabric Filter	PAHs	ACI + Fabric Filter	25,446,261	4,359,610	12	305,355,132	52,315,324	0.27	**193,359,544 ($/ton)**
PEC with New Fabric Filter	AGs	DSI + Fabric Filter	25,783,761	4,064,202	12	309,405,132	48,770,424	5.13	**9,513,924 ($/ton)**
Battery Stacks	AGs	DSI + Fabric Filter + New Stack (with desulfurization)	22,873,652	3,701,624	10	343,104,785	62,236,450	54.3	**1,032,154 ($/ton)**
Battery Stacks	AGs	DSI + Fabric Filter + New Stack (without desulfurization)	22,873,652	5,044,042	5				
Battery Stacks	Hg	ACI + Fabric Filter + New Stack	22,536,152	3,915,379	15	338,042,285	58,730,684	0.049	**599,924 ($/lb)**
Total Industry Cost	Hg	PEC – ACI/Fabric Filter Battery Stack - ACI/Fabric Filter				643,397,417	111,046,008	0.05	**1,117,163 ($/lb)**
Total Industry Cost	PAHs	PEC – ACI/Fabric Filter				305,355,132	52,315,324	0.27	**193,359,544 ($/ton)**
Total Industry Cost	AGs	PEC – DSI/Fabric Filter Battery Stack - DSI/Fabric Filter				652,509,917	111,006,874	59.43	**1,867,859 ($/ton)**
Total Industry Cost – All Pollutants						**1,295,907,334**	**222,052,882**		

*TCI = Total Capital Investment; TAC = Total Annual Cost

[17] Costs are understated based on the technical concerns discussed in this white paper (e.g., battery idling, space constraints, redundant equipment, compatibility studies, rerouting of combustion exhaust).

[18] Baseline emissions are those used in EPA's control cost evaluation (EPA-HQ-OAR-2002-0085-0859_attachment_6.xlsx). Control efficiencies of 90%, 95%, and 80% were used for AGs, Hg, and PAHs, respectively.

REFERENCES

1) Federal Register/Vol. 88, No. 157, Page 5585, August 16, 2023/Proposed Rules.
2) Table 10 – Summary of Proposed Amendments to 40 CFR 63, Subparts 5C and L, Federal Register/Vol. 88, No. 157, Page 55893, August 16, 2023/Proposed Rules.
3) Federal Register/Vol. 88, No. 157, Page 5585, August 16, 2023/Proposed Rules.
4) COETF comments to EPA (Dr. Donna Lee Jones), October 2, 2023.
5) Coke NESHAP Redline Version of Proposed Rule Changes for 40 CFR part 63, subpart CCCCC, July 1, 2023.
6) EPA-450/2-77-019, Sept. 1977. EPA Guideline Series, control of sulfuric acid mist emissions from existing sulfuric acid production units.
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9) Installation Permit Application for USS Proposed C Battery Project, January 2008.
10) Intech 2012 Hein and Kaiser, Air Pollution – A Comprehensive Perspective Environmental Control and Emission Reduction for Coking Plants, Chapter 10, 2012.
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12) US EPA, Summary of Public Comments and Responses for Lime Manufacturing Plants Residual Risk and Technology Review, May 2020.
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14) Schulz. M, and Klaus-Peter Paul Leuchtmann et al, AISTech, 2015; Hyundai Steel and ThyssenKrupp Industrial Solutions USA, Using modern coke oven technology at the new Hyundai Steel coke plant.
15) Dickerman, Jim; and Mike Schantz, Lhoist North America; IMPROVED DSI PERFORMANCE WITH OPTIMIZED HYDRATED LIME, DSI with Sorbacal®SP, c. 2013.
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17) COETF "Compliance Schedule Concerns 020924.pdf" to EPA, February 9, 2024.

APPENDIX A. APC COST DATA BACKUP

Costs of Controls for the Byproduct Recovery Plant Battery Stacks

Summary of Capital and Annual Costs	No. APCD Configurations[1]	ABC-Tarrant-AL	AM-BurnsHarbor-IN	AM-Monessen-PA	AM-Warren-OH	EES-RiverRouge-MI	USS-Clairton-PA		
		2	2	2	1	1	7		
Capital Cost[3]	**Unit Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Industry Total Cost ($2022)**	
Ductwork	$33,761	$67,522	$67,522	$67,522	$33,761	$33,761	$236,327	$506,414	
Activated Carbon Injection Capital Costs	$412,500	$825,000	$825,000	$825,000	$412,500	$412,500	$2,887,500	$6,187,500	
Dry Sorbent Injection Capital Costs	$750,000	$1,500,000	$1,500,000	$1,500,000	$750,000	$750,000	$5,250,000	$11,250,000	
Replacement Stack Capital Costs	$10,000,000	$20,000,000	$20,000,000	$20,000,000	$10,000,000	$10,000,000	$70,000,000	$150,000,000	
Fabric Filter Capital Costs	$12,089,891	$24,179,783	$24,179,783	$24,179,783	$12,089,891	$12,089,891	$84,629,240	$181,348,370	
Total Capital Cost (ACI + Fabric Filter + Stack)	**$22,536,152**	**$45,072,305**	**$111,341,979**	**$67,162,196**	**$44,626,044**	**$508,513,762**	**$489,101,437**	**$338,042,285**	
Total Capital Cost (DSI + Fabric Filter + Stack)	**$22,873,652**	**$45,747,305**	**$45,747,305**	**$45,747,305**	**$22,873,652**	**$22,873,652**	**$160,115,566**	**$343,104,785**	
Annual Cost	**Unit Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Industry Total Cost ($2022)**	
Ductwork	$12,769	$25,538	$25,538	$25,538	$12,769	$12,769	$89,384	$191,537	
Activated Carbon Injection Annual Costs	$622,243	$1,244,486	$1,244,486	$1,244,486	$622,243	$622,243	$4,355,700	$9,333,642	
Dry Sorbent Injection Annual Costs (sites with desulfurization)	$408,488	$3,501,813	$3,501,813	$816,975	$408,488	$1,750,906	$2,859,414	$12,839,408	
Dry Sorbent Injection Annual Costs (sites without desulfurization)	$1,750,906								
Replacement Stack Annual Costs	$1,380,922	$2,761,844	$2,761,844	$2,761,844	$1,380,922	$1,380,922	$9,666,453	$20,713,829	
Fabric Filter Annual Costs	$1,899,445	$3,798,890	$3,798,890	$3,798,890	$1,899,445	$1,899,445	$13,296,115	$28,491,676	
Total Annual Costs (ACI + Fabric Filter + Stack)	**$3,915,379**	**$7,830,758**	**$17,671,859**	**$11,111,125**	**$7,195,746**	**$76,083,453**	**$76,613,157**	**$58,730,684**	
Total Annual Costs (DSI + Fabric Filter + Stack)	**$5,044,042**	**$10,088,085**	**$10,088,085**	**$7,403,248**	**$3,701,624**	**$5,044,042**	**$25,911,367**	**$62,236,450**	
Uncontrolled Pollutant (Ton/yr)		**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY[4]**	**Industry Total TPY**	
Uncontrolled Hg Emission Rate (Ton/yr)		1.3E-03	3.0E-02	6.5E-04	2.1E-03	5.8E-03	1.1E-02	**0.052**	
Uncontrolled Acid Gas Emission Rate (Ton/yr)		2.3E+00	1.5E+01	1.7E+00	4.6E+00	1.3E+01	2.4E+01	**60.3**	
Uncontrolled HCN Emission Rate (Ton/yr)		9.9E-01	2.3E+00	8.7E-02	2.8E-01	7.5E-01	2.7E-01	**4.7**	
Uncontrolled Total HAP[2] Emission Rate (Ton/yr)		3.2E+00	1.8E+01	1.8E+00	4.9E+00	1.3E+01	2.4E+01	**65**	
Pollutant Reductions (Ton/yr)		**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Industry Total TPY**	
Hg Emission Reduction w/ ACI		1.2E-03	2.9E-02	6.2E-04	2.0E-03	5.5E-03	1.1E-02	**0.049**	95.00%
Acid Gas Reduction w/ DSI		2.0E+00	1.4E+01	1.6E+00	4.2E+00	1.1E+01	2.1E+01	**54.3**	90.00%
HCN Reduction (Not Available)		0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	**0.0**	0.00%
Total HAP[2] Reduction		2.0E+00	1.4E+01	1.6E+00	4.2E+00	1.1E+01	2.1E+01	**54.32**	
Pollutant Cost Effectiveness ($/Ton)		**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Industry Total $/Ton ($/lb Mercury)**	
Hg Cost Effectiveness ($/lb) w/ ACI and FF (Stack)		$3,141,995	$305,170	$9,006,760	$1,777,221	$6,876,740	$3,622,354	**$599,923**	
Acid Gas Cost Effectiveness ($/Ton) w/ DSI and FF (Stack)		$4,482,659	$653,280	$4,246,594	$800,886	$399,378	$1,097,475	**$1,032,154**	
HCN Cost Effectiveness ($/Ton) (Not Available)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Total HAP[2] Cost Effectiveness ($/Ton) w/ Ductwork+ACI+DSI+FF (Stack)		$5,591,724	$813,715	$5,509,441	$1,038,956	$498,253	$1,423,693	**$1,317,641**	

[1] There are six ByProduct recovery coke plants that have a total of 15 Battery Stacks.

[2] Where Total HAP is the sum of Hg, Acid Gas, and HCN emissions for which the EPA is setting MACT floors.

[3] Costs noted above do not consider numerous concerns regarding retrofitting of these emissions sources. For example, there are significant space constraints such that vertical construction/design may be needed. Moreover, battery stacks are natural draft with the underfire stream predominantly underground. The impacts of added fans and equipment will need to be studied to ensure adequate heating of the batteries, as well as enough physical space to install additional equipment. All this will pose crucial obstacles and engineering challenges for any new add-on equipment. Furthermore, changes to the underfiring system will necessitate the planning and scheduling of battery outages, during which purchased natural gas will be needed to keep the battery hot; all coke production would cease; and battery refractory brick and other equipment could suffer unanticipated damage, adding more time and expense to address. Costs for loss of production are also not considered. Electrical needs will also need to be reviewed.

[4] Emission rates reflect removal of Batteries 1,2 and 3 at the Clairton byproduct recovery plant which have been permanently closed.

Activated Carbon Injection Model Costs (ACI Only)[1,2,3]

Parameters		
Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	138,402	(updated to remove any batteries no longer operable)
Exhaust Gas Flow Rate, dscfm (Q)	68,684	
Operating Labor Rate, $/hr (LR)	$30.52	
Activated Carbon Cost, $/lb (ACC)	$0.75	Cost for FF from IPM,[2] cost for scrubber from email from Albemarle[3]
Dust Disposal Cost, $/Ton (DDC, Non-Hazardous)	$40.00	Cost from EPA
Dust Disposal Cost, $/Ton (DDC, Hazardous)	$400.00	Cost from EPA
Annual interest rate (fractional):	0.075	
Economic life (years):	20	
Capital Recovery Factor (CRF)	0.098092192	CRF calculated assuming 20-year equipment life and 7.5% interest
GDP, 2022	126.45	
GDP, 2008	94.419	
GDP, 1991	65.783	
ACI Adjustment Factor (AF)	0.95	Calculated control efficiency
ACI Injection Rate (lb/MMacf)	6	Updated based on Sargent & Lundy Study[4]
Total Capital Investment, $ (TCI)(1 system)	$275,000	Reflects high level budget estimates from vendor (2024)
TCI, $ (redundant system components)	$137,500	(50% estimate)
TCI, $ (system and redundant parts)	**$412,500**	
Direct Annual Cost, $/yr (DAC)		
Operating Labor	$8,355	Calculated using (0.25 hr/8-hr shift) x H x LR
Supervisory Labor	$1,253	Calculated using 0.15 x Operating Labor
Maintenance	$82,500	Calculated using 0.2 x TCI
Activated Carbon	$330,622	
Dust Disposal (Non-Hazardous)	$8,728	Calculated using ACI injection rate, 99% capture efficiency, and non-hazardous disposal cost
Dust Disposal (Hazardous)	$87,284	Calculated using ACI injection rate, 99% capture efficiency, and hazardous disposal cost
Indirect Annual Cost, $/yr (IAC)		
Overhead	$55,265	Calculated using 0.6 x (Labor + Maintenance)
Property Tax, Insurance, & Admin	$16,500	Calculated using 0.04 x TCI
Capital Recovery	$40,463	Calculated using CRF x TCI
Total Annual Cost (Non-Hazardous)	$543,687	Sum of DAC + IAC
Total Annual Cost (Hazardous)	$622,243	Sum of DAC + IAC
Total Annual Cost (Hazardous)	**$622,243**	(used in total cost estimates)

[1] Memorandum from Amanda Singleton and Susan McClutchey, ERG to Jim Eddinger, EPA, Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emissions Standards for Hazardous Air Pollutants - Major Source, Appendix F, January 2011.

[2] Sargent & Lundy, IPM Model - Revisions to Cost and Performance for APC Technologies, Mercury Control Cost Development Methodology Final, March 2011

[3] Email from Daryl Lipscomb, Albemarle to Bradley Nelson, EC/R, 8/30/2011

[4] Sargent & Lundy, IPM Model - Revisions to Cost and Performance for APC Technologies, Mercury Control Cost Development Methodology Final, March 2023

Battery Stack - ACI Injection Rate Calculation

0.46	MMSCF/hr	Example Battery (Monessen (PA) Batt. 2 Comb Stack - 2016 ICR test)
500	btu/scf	estimate
230	MMBtu/hr	(heat input)
2014800	MMBtu/yr	
2.015	Tbtu/yr	
3.86E-06	lb Hg/ton coke (uncontrolled, from EPA's Baseline TP values)	
2.20E-04	tpy Hg (uncontrolled, from EPA's Baseline TP values)	
2.19E-01	lb/Tbtu uncontrolled	
1.09E-02	lb/Tbtu controlled	
6	**lb/Mmacf**	**Using Premium/Baghouse**

Injection Rate / Emission Rate Calculations

Current Injection Rate:

$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

Where,

x is the **current** injection rate (lb/MMacf),
y is the **current** emission rate (lb/TBtu), and
a and b are coefficients dependent on the fuel, particulate collection device, and PAC type (see table below).

Option 1 – Achievable Emission Rate based on New Injection Rate (Recommended Maximum 20% Increase):

$$y = a * e^{b*x}$$

Option 2 – New Injection Rate based on New Emission Rate (Per Minimum Limits Above):

$$x = \frac{\ln\left(\frac{y}{a}\right)}{b}$$

Where,

x is the **new** injection rate (lb/MMacf),
y is the **new** emission rate (lb/TBtu), and
a and b are coefficients dependent on the fuel, particulate collection device, and PAC type (see table below).

Fuel Type	PRB or Bituminous		Lignite	
Particulate Control Type	Baghouse	ESP	Baghouse	ESP
Coefficient 'a'				
Premium PAC	4.3552	4.3552	21.567	21.567
Standard PAC	3.7609	3.7609	25.886	25.886
Coefficient 'b'				
Premium PAC	-0.988	-0.593	-1.647	-1.086
Standard PAC	-0.636	-0.381	-0.987	-0.69

New Baghouse Model Costs[1,2]

Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	138,402	(revised removal of sites no longer in operation)
Exhaust Gas Flow Rate, dscfm (Q)	68,684	
Retrofit Factor	1.25	(conservatively set at 1.25, consistent with EPA value for ductwork)
Total Installed, $ (TCI)	$9,671,913	BMB ($) = J*B*L^0.81; J = 530 for a 6.0 Air-to-Cloth unit
TCI, $ (redundant system components)	$2,417,978	(25% estimate for extra compartments, fans, etc.)
TCI $	**$12,089,891**	BMB ($) = J*B*L^0.81; J = 530 for a 6.0 Air-to-Cloth unit

1. Cost calculated per Table 3 of https://www.epa.gov/system/files/documents/2021-09/attachment_5-7_pm_control_cost_development_methodology.pdf
2. Note that in response to the proposed II&S rules, industry estimated $7.5 million for purchased cost of a new baghouse with ACI for a BOF. (EPA-HQ-OAR-2002-0083-1612_attachment_1.pdf)

Annual Costs

Operating factor (hr/yr):	8,760	
Operating labor rate ($/hr):	$30.52	
Maintenance labor rate ($/hr):	$30.52	
Operating labor factor (hr/sh):	2	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Maintenance labor factor (hr/sh):	1	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Annual interest rate (fraction):	0.075	
Control system life (years):	20	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor:	0.098092192	
Bag life (years):	2	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor (bags):	0.556927711	
Taxes, insurance, admin. factor:	0.04	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)

Item		
Oper. labor	$66,839	
Supv. labor	$10,026	15% Operating Labor
Maint. labor	$33,419	
Maint. matl.	$33,419	Equal to maint. Labor
Overhead	$86,222	60% of (Oper, Supv, Maint. Costs)
Tax,ins.,adm	$483,596	
Cap. recov.	$1,185,924	
Total Annual Cost	**$1,899,445**	

New Battery Stack Model Costs

Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	138,402	(revised removal of sites no longer in operation)
Exhaust Gas Flow Rate, dscfm (Q)	68,684	
Retrofit Factor	1.25	(conservatively set at 1.25 consistent with EPA value for ductwork)
Total Capital Investment ($)	**$10,000,000**	(example from battery stack project in 2019 was greater than $10 million including temporary stack)

Annual Costs

Annual interest rate (fraction):	0.075	
Control system life (years):	20	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor:	0.098092192	
Bag life (years):	2	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor (bags):	0.556927711	
Taxes, insurance, admin. factor:	0.04	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)

Item	
Tax,ins.,adm	$400,000
Cap. recov.	$980,922
Total Annual Cost	**$1,380,922**

Dry Sorbent Injection Model Costs (DSI Only at Sites with Desulfurization)[1]

Parameters		
Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	138,402	(updated to remove any batteries no longer operable)
Exhaust Gas Flow Rate, dscfm (Q)	68,684	
Operating Labor Rate, $/hr (LR)	$30.52	
Annual interest rate (fractional):	0.075	
Economic life (years):	20	
Capital Recovery Factor (CRF)	0.098092192	CRF calculated assuming 20-year equipment life and 7.5% interest
GDP, 2022	126.45	
GDP, 2008	94.419	
GDP, 1991	65.783	
Total Capital Investment, $ (TCI)(1 system)	$500,000	Reflected of high level budget estimates from vendor (2024)
TCI, $ (redundant system components)	$250,000	(50% estimate)
TCI, $ (system and redundant parts)	**$750,000**	
Direct Annual Cost, $/yr (DAC)		
Operating Labor	$8,355	Calculated using (0.25 hr/8-hr shift) x H x LR
Supervisory Labor	$1,253	Calculated using 0.15 x Operating Labor
Maintenance	$150,000	Calculated using 0.2 x TCI
Approximate SO2 emissions (tpy per stack)	57.33	
Lime Cost ($/yr, 2010) = 0.3 * lbs SO2/yr	$34,400	
Lime Cost ($/yr, 2023) = 2010 $/yr * CEPCI 2023/ CEPCI 2010	$49,546	Given the relative emissions of SO2 and HCl, control will primarily result in reductions of SO2. The amount of lime injection must consider SO2 emissions, although HCl is the target pollutant for this cost estimate. SO2 based on 2020 air emissions data published for Clairton (PA) and Monessen (PA) byproduct recovery coke plants.
Indirect Annual Cost, $/yr (IAC)		
Overhead	$95,765	Calculated using 0.6 x (Labor + Maintenance)
Property Tax, Insurance, & Admin	$30,000	Calculated using 0.04 x TCI
Capital Recovery	$73,569	Calculated using CRF x TCI
Total Annual Cost	**$408,488**	Sum of DAC + IAC

[1] Memorandum from Amanda Singleton and Susan McClutchey, ERG to Jim Eddinger, EPA, Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emissions Standards for Hazardous Air Pollutants - Major Source, Appendix F, January 2011.

Dry Sorbent Injection Model Costs (DSI Only at Sites without Desulfurization)[1]

Parameters		
Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	138,402	(updated to remove any batteries no longer operable)
Exhaust Gas Flow Rate, dscfm (Q)	68,684	
Operating Labor Rate, $/hr (LR)	$30.52	
Annual interest rate (fractional):	0.075	
Economic life (years):	20	
Capital Recovery Factor (CRF)	0.098092192	CRF calculated assuming 20-year equipment life and 7.5% interest
GDP, 2022	126.45	
GDP, 2008	94.419	
GDP, 1991	65.783	
Total Capital Investment, $ (TCI)(1 system)	$500,000	Reflected of high level budget estimates from vendor (2024)
TCI, $ (redundant system components)	$250,000	(50% estimate)
TCI, $ (system and redundant parts)	**$750,000**	
Direct Annual Cost, $/yr (DAC)		
Operating Labor	$8,355	Calculated using (0.25 hr/8-hr shift) x H x LR
Supervisory Labor	$1,253	Calculated using 0.15 x Operating Labor
Maintenance	$150,000	Calculated using 0.2 x TCI
Approximate SO2 emissions (tpy per stack)	1610.77	
Lime Cost ($/yr, 2010) = 0.3 * lbs SO2/yr	$966,462	
Lime Cost ($/yr, 2023) = 2010 $/yr * CEPCI 2023/ CEPCI 2010	$1,391,964	Given the relative emissions of SO2 and HCl, control will primarily result in reductions of SO2. The amount of lime injection must consider SO2 emissions, though HCl is the target pollutant for this cost estimate. SO2 based on average of 2022 combustion stack emissions for Burns Harbor (IN).
Indirect Annual Cost, $/yr (IAC)		
Overhead	$95,765	Calculated using 0.6 x (Labor + Maintenance)
Property Tax, Insurance, & Admin	$30,000	Calculated using 0.04 x TCI
Capital Recovery	$73,569	Calculated using CRF x TCI
Total Annual Cost	**$1,750,906**	Sum of DAC + IAC

[1] Memorandum from Amanda Singleton and Susan McClutchey, ERG to Jim Eddinger, EPA, Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emissions Standards for Hazardous Air Pollutants - Major Source, Appendix F, January 2011.

Costs for Pushing Emissions Control (PEC) Systems

Summary of Capital and Annual Costs	No. PEC Systems[1]	ABC-Tarrant-AL	AM-BurnsHarbor-IN	AM-Monessen-PA	AM-Warren-OH	EES-RiverRouge-MI	USS-Clairton-PA		
		3	2	1	1	1	4		
Capital Cost[3]	**Unit Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Industry Total Cost ($2022)**	
Ductwork	$33,761	$101,283	$67,522	$33,761	$33,761	$33,761	$135,044	$405,132	
Activated Carbon Injection Capital Cost	$412,500	$1,237,500	$825,000	$412,500	$412,500	$412,500	$1,650,000	$4,950,000	
New Fabric Filter	$25,000,000	$75,000,000	$50,000,000	$25,000,000	$25,000,000	$25,000,000	$100,000,000	$300,000,000	
Dry Sorbent Injection Capital Cost	$750,000	$2,250,000	$1,500,000	$750,000	$750,000	$750,000	$3,000,000	$9,000,000	
Total Capital Cost (ACI + Fabric Filter)	$25,446,261	$76,338,783	$50,892,522	$25,446,261	$25,446,261	$25,446,261	$101,785,044	$305,355,132	
Total Capital Cost (DSI + Fabric Filter)	$25,783,761	$77,351,283	$51,567,522	$25,783,761	$25,783,761	$25,783,761	$103,135,044	$309,405,132	
Annual Cost	**Unit Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Total Facility Cost ($2022)**	**Industry Total Cost ($2022)**	
Ductwork	$13,221	$39,664	$26,443	$13,221	$13,221	$13,221	$52,886	$158,657	
Activated Carbon Injection Annual Cost	$664,159	$1,992,476	$1,328,317	$664,159	$664,159	$664,159	$2,656,634	$7,969,903	
New Fabric Filter	$3,682,230	$11,046,691	$7,364,461	$3,682,230	$3,682,230	$3,682,230	$14,728,921	$44,186,763	
Dry Sorbent Injection Capital Cost	$368,750	$1,106,251	$737,501	$368,750	$368,750	$368,750	$1,475,001	$4,425,004	
Total Annual Costs (ACI + Fabric Filter)	$4,359,610	$13,078,831	$8,719,221	$4,359,610	$4,359,610	$4,359,610	$17,438,441	$52,315,324	
Total Annual Costs (DSI + Fabric Filter)	$4,064,202	$12,192,606	$8,128,404	$4,064,202	$4,064,202	$4,064,202	$16,256,808	$48,770,424	
Uncontrolled Pollutant (Ton/yr)		**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Industry Total TPY**	
Uncontrolled Acid Gas Emission Rate (Ton/yr)		3.79E-01	2.26E+00	1.96E-01	2.30E-01	6.29E-01	2.00E+00	**5.70**	
Uncontrolled HCN Emission Rate (Ton/yr)		2.36E-01	7.95E-01	1.24E-01	9.33E-02	2.55E-01	8.11E-01	**2.31**	
Uncontrolled Hg Emission Rate (Ton/yr)		2.65E-05	2.10E-04	3.74E-05	4.00E-05	1.09E-04	3.48E-04	**0.0008**	
Uncontrolled PAH Emission Rate (Ton/yr)		1.71E-01	4.73E-02	8.42E-03	9.00E-03	2.46E-02	7.83E-02	**0.34**	
Uncontrolled Total HAP[2] Emission Rate (Ton/yr)		7.86E-01	3.10E+00	3.28E-01	3.33E-01	9.09E-01	2.89E+00	**8.35**	
Pollutant Reductions (Ton/yr)		**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Total Facility TPY**	**Industry Total TPY**	
Acid Gas Reduction w/ DSI		3.41E-01	2.03E+00	1.76E-01	2.07E-01	5.66E-01	1.80E+00	**5.13**	90.00%
HCN Reduction (Not Available)		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	**0.00**	0.00%
Hg Reduction w/ACI		2.52E-05	2.00E-04	3.55E-05	3.80E-05	1.04E-04	3.30E-04	**0.0007**	95.00%
PAH Reduction w/ACI		1.37E-01	3.78E-02	6.73E-03	7.20E-03	1.97E-02	6.26E-02	**0.27**	80.00%
Total HAP[2] Reduction		4.77E-01	2.07E+00	1.83E-01	2.14E-01	5.86E-01	1.87E+00	**5.40**	
Pollutant Cost Effectiveness ($/Ton)		**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Total Facility $/Ton ($/lb Mercury)**	**Industry Total $/Ton ($/lb Mercury)**	
Acid Gas Cost Effectiveness ($/Ton) w/DSI		$35,770,190	$3,997,621	$23,047,434	$19,612,208	$7,177,169	$9,020,491	**$9,513,924**	
HCN Cost Effectiveness ($/Ton) (Not Available)		N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Hg Cost Effectiveness ($/lb) w/ACI		$259,338,475	$21,838,895	$61,357,851	$57,385,689	$21,000,532	$26,394,127	**$35,710,236**	
PAH Cost Effectiveness ($/Ton) w/ACI		$95,799,475	$230,477,756	$647,542,821	$605,622,434	$221,630,058	$278,551,601	**$193,359,544**	
Total HAP[2] Cost Effectiveness ($/Ton) w/Ductwork+ACI+DSI		$6,573,819	$1,010,100	$5,713,162	$22,047,266	$1,785,076	$2,243,539	**$3,008,017**	

[1] There are six existing byproduct recovery coke plants with a total of 12 PEC systems.

[2] Where Total HAP is the sum of Acid Gas, HCN, Hg, and PAH emissions for which the EPA is setting MACT floors.

[3] Costs noted above do not consider numerous concerns regarding retrofitting of these emissions sources, including potential retrofit of existing PM controls. For example, there are significant space constraints such that vertical construction/design may be needed. Electrical needs will also need to be reviewed.

Activated Carbon Injection Model Costs (ACI Only) [1,2,3]

Parameters		
Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	153,807	(revised removal of sites no longer in operation)
Exhaust Gas Flow Rate, dscfm (Q)	127,926	
Operating Labor Rate, $/hr (LR)	$30.52	
Activated Carbon Cost, $/lb (ACC)	$0.75	Cost for FF from IPM,[2] cost for scrubber from email from Albemarle [3]
Dust Disposal Cost, $/Ton (DDC, Non-Hazardous)	$40.00	Cost from EPA
Dust Disposal Cost, $/Ton (DDC, Hazardous)	$400.00	Cost from EPA
Annual interest rate (fractional):	0.075	
Economic life (years):	20	
Capital Recovery Factor (CRF)	0.098092192	CRF calculated assuming 20-year equipment life and 7.5% interest
GDP, 2022	126.45	
GDP, 2008	94.419	
GDP, 1991	65.783	
ACI Adjustment Factor (AF)	0.95	Calculated control efficiency
ACI Injection Rate (lb/MMacf)	6.0	Updated based on Sargent & Lundy Study[4] (Based on same rate as battery stack review given similar flowrates and equivalent or smaller concentrations)
Total Capital Investment, $ (TCI)(1 system)	$275,000	Reflected of high level budget estimates from vendor
TCI, $ (redundant system components)	$137,500	(50% estimate)
TCI, $ (system and redundant parts)	**$412,500**	
Direct Annual Cost, $/yr (DAC)		
Operating Labor	$8,355	Calculated using (0.25 hr/8-hr shift) x H x LR
Supervisory Labor	$1,253	Calculated using 0.15 x Operating Labor
Maintenance	$82,500	Calculated using 0.2 x TCI
Activated Carbon	$363,784	
Dust Disposal (Non-Hazardous)	$9,604	Calculated using ACI injection rate, 99% capture efficiency, and non-hazardous disposal cost
Dust Disposal (Hazardous)	$96,039	Calculated using ACI injection rate, 99% capture efficiency, and hazardous disposal cost
Indirect Annual Cost, $/yr (IAC)		
Overhead	$55,265	Calculated using 0.6 x (Labor + Maintenance)
Property Tax, Insurance, & Admin	$16,500	Calculated using 0.04 x TCI
Capital Recovery	$40,463	Calculated using CRF x TCI
Total Annual Cost (Non-Hazardous)	$577,724	Sum of DAC + IAC
Total Annual Cost (Hazardous)	$664,159	Sum of DAC + IAC
Total Annual Cost (Hazardous)	**$664,159**	(used in total cost estimates)

[1] Memorandum from Amanda Singleton and Susan McClutchey, ERG to Jim Eddinger, EPA, Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emissions Standards for Hazardous Air Pollutants - Major Source, Appendix F, January 2011.

[2] Sargent & Lundy, IPM Model - Revisions to Cost and Performance for APC Technologies, Mercury Control Cost Development Methodology Final, March 2011

[3] Email from Daryl Lipscomb, Albemarle to Bradley Nelson, EC/R, 8/30/2011

[4] Sargent & Lundy, IPM Model - Revisions to Cost and Performance for APC Technologies, Mercury Control Cost Development Methodology Final, March 2023

New PEC Baghouse Model Costs (and Supporting Upgrades) [1,2]

Total Installed, $ (TCI)	**$25,000,000**	Cliffs Warren Site engineering estimate

1. Cost calculated per Table 3 of https://www.epa.gov/system/files/documents/2021-09/attachment_5-7_pm_control_cost_development_methodology.pdf

Annual Costs

Operating factor (hr/yr):	8,760	
Operating labor rate ($/hr):	$30.52	
Maintenance labor rate ($/hr):	$30.52	
Operating labor factor (hr/sh):	2	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Maintenance labor factor (hr/sh):	1	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Annual interest rate (fraction):	0.075	
Control system life (years):	20	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor:	0.098092192	
Bag life (years):	2	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)
Capital recovery factor (bags):	0.556927711	
Taxes, insurance, admin. factor:	0.04	(from EPA baghouse cost template in EPA-HQ-OAR-2002-0085-0859_attachment_5.xlsx)

Item		
Oper. labor	$66,839	
Supv. labor	$10,026	15% Operating Labor
Maint. labor	$33,419	
Maint. matl.	$33,419	Equal to maint. Labor
Overhead	$86,222	60% of (Oper, Supv, Maint. Costs)
Tax,ins.,adm	$1,000,000	
Cap. recov.	$2,452,305	
Total Annual Cost	**$3,682,230**	

Dry Sorbent Injection Model Costs (DSI Only)[1]

Parameters		
Control Device	Fabric Filter	
Annual Operating Hours, hr/yr (H)	8760	
Exhaust Gas Flow Rate, acfm (Qa)	153,807	(updated to remove batteries no longer in operation)
Exhaust Gas Flow Rate, dscfm (Q)	127,926	
Operating Labor Rate, $/hr (LR)	$30.52	
Annual interest rate (fractional):	0.075	
Economic life (years):	20	
Capital Recovery Factor (CRF)	0.098092192	CRF calculated assuming 20-year equipment life and 7.5% interest
GDP, 2022	126.45	
GDP, 2008	94.419	
GDP, 1991	65.783	
Total Capital Investment, $ (TCI)(1 system)	$500,000	Reflective of high level budget estimates from vendor (2024)
TCI, $ (redundant system components)	$250,000	(50% estimate)
TCI, $ (system and redundant parts)	**$750,000**	
Direct Annual Cost, $/yr (DAC)		
Operating Labor	$8,355	Calculated using (0.25 hr/8-hr shift) x H x LR
Supervisory Labor	$1,253	Calculated using 0.15 x Operating Labor
Maintenance	$150,000	Calculated using 0.2 x TCI
Approximate SO2 emissions (tpy per stack)	11.35	
Lime Cost ($/yr, 2010) = 0.3 * lbs SO2/yr	$6,810	
Lime Cost ($/yr, 2023) = 2010 $/yr * CEPCI 2023/ CEPCI 2010	$9,808	Given the relative emissions of SO2 and HCl, control will primarily result in reductions of SO2. The amount of lime injection must consider SO2 emissions, although HCl is the target pollutant for this cost estimate. SO2 based on 2020 air emissions data published for Clairton (PA) and Monessen (PA) byproduct recovery coke plants.
Indirect Annual Cost, $/yr (IAC)		
Overhead	$95,765	Calculated using 0.6 x (Labor + Maintenance)
Property Tax, Insurance, & Admin	$30,000	Calculated using 0.04 x TCI
Capital Recovery	$73,569	Calculated using CRF x TCI
Total Annual Cost	**$368,750**	Sum of DAC + IAC

[1] Memorandum from Amanda Singleton and Susan McClutchey, ERG to Jim Eddinger, EPA, Revised Methodology for Estimating Control Costs for Industrial, Commercial, Institutional Boilers and Process Heaters National Emissions Standards for Hazardous Air Pollutants - Major Source, Appendix F, January 2011.

APPENDIX B. VENDOR OUTREACH

Company Name/Vendor	Technology
LDX Solutions	DSI, CSR, FF, ACI
Babcock & Wilcox	DSI, ACI
Calgon Carbon Corporation	DSI, ACI
Solvay (SolvAir Solutions)	DSI
Tri-Mer Corporation	Wet Scrubbing

APPENDIX C. MODEL BATTERY PARAMETERS

Parameter	PEC System (with existing baghouse)	Battery Stack
Flowrate (dscfm)	~135,000	~40,000 to 60,000
Temperature (degrees Fahrenheit)	~115	~500
Moisture (%)	~2	~14
Polycyclic Aromatic Hydrocarbons Range (µg/m3)	300 to 1,100	Not applicable
Hydrogen Cyanide Range (µg/m3)	1,000 to 4,000	100 to 1,200
Mercury Range (µg/m3)	1 to 5	20 to 100
Acid Gas Range (Hydrogen Chloride and Hydrogen Fluoride) (µg/m3)	4,000 to 20,000	40,000 to 180,000

*The parameters listed above are a simplification for the purposes of initial vendor outreach and do not necessarily reflect any given individual byproduct recovery coke battery.
**Approximate values.