ARCHITECT OF THE CAPITOL

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July 24, 2023

Mr. Joseph Jakuta
Department of Energy and Environment
Air Quality Division
Monitoring and Assessment Branch
1200 First Street, NE, Fifth Floor
Washington, DC 20002

Mr. Jakuta:

I appreciate the opportunity to comment on the Department of Energy and Environment's (DOEE) proposed response to the Architect of the Capitol's (AOC) Capitol Power Plant (CPP) Alternative nitrogen oxides (NOx) reasonably available control technology (RACT) submission.

First, I want to reiterate that the AOC and CPP are committed environmental stewards and have proactively taken steps over the past decade to dramatically reduce air emissions and increase energy efficiency. Most notably, CPP has transitioned away from burning coal and instead now utilizes a state-of-the-art cogeneration system to more efficiently produce steam and electricity. CPP is also developing a new utility master plan to improve utility energy services across the Capitol complex in a more efficient, resilient, and environmentally responsible manner. CPP looks forward to working with DOEE on these future improvements.

Enclosed are comments and a revised Alternative NOx RACT submission which incorporates updated emissions and operational limits and a revised cost effectiveness assessment. These limits are responsive to DOEE's regulatory intentions as they provide a more aggressive, enforceable guarantee that lowers the maximum amount of NOx that CPP could potentially emit. Once this reduction in potential emissions is incorporated, an objective cost-benefit analysis clearly demonstrates that add-on NOx controls are not economically effective and therefore are not mandated under the regulation.

If you have any questions or would like to discuss our submission, please do not hesitate to contact me. Thank you for your consideration of our comments and revised submission.

Sincerely,

Potter, Christopher

Digitally signed by Potter, Christopher
Date: 2023.07.24 11:24:00 -04'00'

Christopher Potter
Director, Utilities and Power Plant Operations
Architect of the Capitol
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Enclosure

**Attachment 1 – Technical Comments**

**Comment #1: CPP is amending the CPP Alternative NOx RACT submission to take limitations which clearly define allowable emissions per boiler so that a proper cost effectiveness analysis can be completed on Boilers 3-7.**

CPP performed a cost effectiveness analysis using actual emissions in our Alternative RACT submission. DOEE evaluated our submission based on a cost effectiveness analysis using unit specific allowable emissions.

While both approaches can be valid, CPP's amended proposal to lower potential NOx emission maximums obviates any need to adjudicate which is most appropriate here. Updating emissions and operating limits to clearly define allowable $NO_x$ limitations on Boilers 3 through 7 yields an accurate allowable emissions rate for each unit. With these limitations, a more robust cost effectiveness analysis can be completed, which reaches the same practical conclusion regardless of whether allowable or actual emissions are used.

*Comment #1a: CPP is updating Alternative RACT Limitations to clearly establish allowable emissions limits on each boiler for Boilers 3-7*

CPP is updating the following limitations to be incorporated as part of our Alternative RACT submission. These limitations will clearly establish allowable $NO_x$ emissions rates on a tons per year basis for Boilers 3 through 7:

- For Boiler 3:
    - Annual fuel input limitations, in the form of a 12-month rolling total limit of 1,069,730 gallons of fuel oil and 748.8 million standard cubic feet (MMscf) of natural gas. These limits are already in place, see Condition III.b of Permit No. 6576.
    - A $NO_x$ emission rate limit of 0.15 lb/MMBtu as measured on a 30-day rolling average from the combined West Stack. This would be more stringent than the current 0.2 lb/MMBtu limit.
- For Boilers 4-7 (each boiler will have the same limitations as the units are of similar design):
    - Annual fuel input limitations, in the form of a 12-month rolling total limit of 408,000 million British thermal units (MMBtu) per boiler combined between heat input from natural gas and #2 fuel oil.
    - A $NO_x$ emission rate limit of 0.15 lb/MMBtu as measured on a 30-day rolling average from the combined West Stack. This would be more stringent than the current 0.25 lb/MMBtu limit.

By accepting these limitations, the allowable emissions rates on an annual basis will be as follows: 68.3 tons per year (tpy) for Boiler 3 and 30.6 tpy each for Boilers 4 through 7.

This information has been included in the enclosed revised Alternative RACT submission.

*Comment #1b: Based on these Alternative RACT Limitations and calculated emission rates, the cost effectiveness assessment should be corrected and updated.*

CPP has recomputed the RACT cost effectiveness analysis using the unit specific $NO_x$ allowable emission rates listed above. In our updated analysis, we considered and updated the following:

- The estimated cost to install the control technologies did not change, however the cost values were updated to account for higher interest rates and shorter service lives based on current conditions. Specifically, CPP has updated the analyses to use a 15-year equipment life and a 5.5 percent interest rate. These values are justified for CPP based on current conditions and were acceptable to DOEE as shown within other approved Alternative RACT Plans in DOEE's proposed rulemaking documents.
- Using the updated annualized control cost estimates for LNB+FGR (the combination of technologies likely necessary to assure compliance with the presumptive RACT level) and the proposed unit-specific allowable emission rates, Table 1 provides an updated cost effectiveness estimate for both reductions in terms of actual emissions and allowable emissions reduced.

**Table 1. Cost Effectiveness Summary**

| **Emissions Scenario** | **Boiler 3 Cost Effectiveness<br><br>($/ton removed)** | **Boiler 4-7 Cost Effectiveness<br><br>($/ton removed)** |
|---|---|---|
| Actual Emissions | $47,732 | $30,133 to $57,683 |
| Updated Allowable Emissions | $8,516 | $13,461 |

*Comment #1c: The Cost Effectiveness Analysis with defined NOx allowable emissions limits for each boiler demonstrate that LNB+FGR is not cost effective and thus not RACT.*

As demonstrated in Table 1 above, the cost effectiveness evaluations show that add-on NOx controls do not meet RACT given their excessive costs. We have also provided proposed permit language for DOEE to consider when incorporating these limits in a final permit or rule in the revised Alternate RACT plan.

**Comment #2: Request for additional information regarding DOEE cost effectiveness assumptions to confirm cost effectiveness calculations and consistency with existing limitations.**

- What is the basis for the listed 7,657 hours per year of operation? This hourly emission limitation does not directly appear in any existing permits for these boilers and would result in exceeding existing fuel usage limitations for Boiler 3.
- How did DOEE's estimated allowable emission rates incorporate the PAL limitation? The combined total appears to exceed the PAL.

- What is the justification for DOEE's use of differing allowable emission rates for Boilers 4 through 7? These units are of similar design so the allowable emission rates should be the same, however they are not the same in DOEE's supporting records.
- Were fuel oil emissions included in the calculation of allowable or controlled emissions?

**Comment #3: The Final Rule should include a Compliance Extension**

For units subject to an alternative RACT, the final rule will need to accommodate a compliance extension to allow sources adequate time to comply. CPP commented on this aspect of the presumptive RACT rule when it was originally proposed however the issue was not addressed in the final rule.

**Attachment 2 – Revised Alternative NOx RACT Submission**

Included in electronic submission only

# UPDATED $NO_X$ RACT ANALYSIS

## Revision to Report Submitted March 1, 2022

### Architect of the Capitol / U.S. Capitol Power Plant

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Updated July 24, 2023

# TABLE OF CONTENTS

# LIST OF TABLES

# 1. INTRODUCTION

The U.S. Capitol Power Plant (CPP) provides heating and cooling to 23 buildings in the Capitol Complex including the House and Senate office buildings, the U.S. Supreme Court, the U.S. Capitol Building, and the Library of Congress. Additionally, the CPP provides heating and cooling to the U.S. Government Printing Office, Union Station, and the Postal Square Building. Several of the CPP's emission units are subject to the District of Columbia's Reasonably Available Control Technology (RACT) regulations for nitrogen oxides ($NO_X$). CPP submitted an alternative RACT plan on March 1, 2022 which detailed RACT compliance for applicable emission units. CPP is now submitting this updated alternative RACT plan as a revision to the 2022 submission. CPP is submitting a fully updated plan to avoid any confusion with the original submission and this revision replaces all portions of the original plan.

## 1.1 Facility Description

The CPP's operations include five (5) boilers that provide heating to Capitol Hill. Boiler 3 (CU-3) is rated at 203 million British thermal units per hour (MMBtu/hr). The four remaining boilers (CU-4 through CU-7) are each rated 60 MMBtu/hr. Boilers 3 through 7 exhaust to the West Stack. Boilers 3 through 7 are equipped with low $NO_X$ burner technology. CPP also has Chapter 2 permits allowing a temporary boiler rated at up to 99 MMBtu/hr to be brought onsite for up to 180 days at a time and operation of a Cogeneration Plant consisting of a 7.5-megawatt (MW) combustion turbine equipped with a 71.9 MMBtu/hr heat recovery steam generator (HRSG). Table 1-1 provides details of the boilers and cogeneration equipment at the CPP.

**Table 1-1. Boiler and Combustion Turbine Specifications**

| Source | Installation Year | Capacity | Fuel |
|---|---|---|---|
| Boiler 3 (CU-3) | 1952 | 203 MMBtu/hr | Natural Gas<br>Fuel Oil |
| Boiler 4 (CU-4) | 1963 | 60 MMBtu/hr | Natural Gas<br>Fuel Oil |
| Boiler 5 (CU-5) | 1963 | 60 MMBtu/hr | Natural Gas<br>Fuel Oil |
| Boiler 6 (CU-6) | 1963 | 60 MMBtu/hr | Natural Gas<br>Fuel Oil |
| Boiler 7 (CU-7) | 1963 | 60 MMBtu/hr | Natural Gas<br>Fuel Oil |
| Combustion Turbine and HRSG (CT-1 and HRSG-1) | 2015 | 7.5 MW CT<br>71.9 MMBtu/hr HRSG | Natural Gas<br>Fuel Oil |
| Temporary Boiler | Brought onsite as needed up to 180 days at a time | Up to 99 MMBtu/hr | Natural Gas<br>Fuel Oil |

Other $NO_X$ emission sources at the CPP include the following:

- One (1) emergency generator; and
- One (1) emergency fire pump.

## 1.2 Regulatory Review

On November 26, 2021, the Department of Energy and Environment (DOEE) finalized amendments to the District of Columbia Municipal Regulation (DCMR) Title 20 Chapter 8, Air Quality – Asbestos, Sulfur, Nitrogen Oxides, and Lead (20 DCMR 8) for facilities required to meet RACT standards for $NO_X$. Presumptive $NO_X$ limits as established in the finalized regulation under 20 DCMR 805.5(e) and 20 DCMR 805.4 for equipment types operated by the CPP are summarized in Table 1-2.

**Table 1-2. Presumptive $NO_X$ RACT Emission Limits**

| Emission Unit Type | CPP Emission Unit(s) | Emission Unit Size | Presumptive RACT Emission Limit |
|---|---|---|---|
| Combustion Turbines Burning Liquid Fuels | CT-1 and HRSG-1 | >50 MMBtu/hr | 42 parts per million by volume, dry (ppmvd) |
| Non-Coal Fired Units | CU-3 | ≥100 MMBtu/hr | 0.12 lb/MMBtu when burning oil or a combination of fuel oil and natural gas<br><br>0.05 lb/MMBtu when burning natural gas only |
| | CU-4 to CU-7 and Temporary Boiler | ≥25 and <100 MMBtu/hr | 0.09 lb/MMBtu when burning fuel oil[1]<br><br>0.05 lb/MMBtu when burning natural gas only |

If an existing unit is unable to meet these limits, the facility was required to submit, by no later than March 1, 2022, an alternative RACT plan demonstrating that the presumptive limits are not technically or economically feasible. Per 20 DCMR 805.2(c), the components of the alternative RACT application include:

> *1. Demonstration that it is not technically or economically feasible for the emission unit to comply with the new emission limitation.*
> *2. Provide a study of the capabiltiy of the emission unit to apply the following $NO_X$ control options and their expected effectiveness:*
> - *a. Low $NO_X$ Burners (LNB);*
> - *b. Overfire Air (OFA);*
> - *c. Flue gas Recirculation (FGR);*
> - *d. Burners Out Of Services (BOOS);*
> - *e. Selective Non-Catalytic Reduction (SNCR); and,*
> - *f. Selective Catalytic Reduction (SCR).*
>
> *3. Determine an emissions limitation reflecting the application of RACT.*

[1] $NO_X$ emission limit for fuel oil burning is for units that have not taken limits to restrict fuel oil usage to periods of gas curtailment, testing and maintenance. Recognizing the CPP's mission and the criticality for maintaining the continuity of government, the CPP has not taken limits to restrict fuel oil usage on any boilers.

CPP submitted an alternative RACT plan which met the requirements of 20 DCMR 805.2(b) on March 1, 2022. DOEE has recently proposed its determination on CPP's Alternate $NO_x$ Plan. To be complete in our comments on the proposed determination and our comments on the proposal, CPP is submitting this updated plan as a revision to the original submission to revise proposed limitations and provide further technical clarifications based on feedback from DOEE on the original plan along with our comments on the proposed rule.

## 1.3 RACT Requirements

The following sections outline the alternative RACT plan for the applicable sources at the CPP.

### 1.3.1 Exempt Units

Emergency standby engines are not subject to $NO_X$ RACT emission limits per 20 DCMR 805.1(c)(5). Therefore, the emergency generator and emergency fire pump are exempt from RACT requirements and these units are not discussed further in this alternative RACT plan.

### 1.3.2 Presumptive RACT

Sources can choose to comply with presumptive RACT limits set forth in 20 DCMR 805.5(e) and 20 DCMR 805.4, which are summarized in Table 1-2. CPP will comply with the presumptive RACT limits for the following sources:

- Combustion Turbine and HRSG (CT-1 and HRSG-1); and
- Temporary Boiler.

The presumptive RACT limits became effective on January 1, 2023.

### 1.3.3 Case-by-Case RACT Determination

For sources that are unable to meet presumptive RACT limits, facilities must propose an alternative RACT emission limitation (i.e., a "case-by-case RACT limit") and apply for a case-by-case RACT from the DOEE. CPP proposes to comply with alternative RACT emission limits for Boilers 3 through 7 (CU-3 through CU-7).

Section 2 of this application includes the demonstration of the technical and economic feasibiltiy of the $NO_X$ control options and the recommended RACT emissions and operational limitations for affected units at the CPP.

# 2. RACT ANALYSIS

As discussed above, several sources at CPP are subject to a case-by-case RACT determination. This section provides details on the methodology used to determine the proposed RACT.

## 2.1 Top-Down Methodology

Case-by-case RACT determinations are traditionally based on a top-down methodology. Presented below are the five (5) basic steps of the top-down RACT review.

### 2.1.1 Step 1: Identify All Control Technologies

Under Step 1, all available control technologies are identified for each emission unit in question. Per 20 DCMR 805.2, the following $NO_X$ control options must be evaluated:

- LNB;
- OFA;
- FGR;
- BOOS;
- SNCR; and
- SCR.

### 2.1.2 Step 2: Eliminate Technically Infeasible Options

After control technologies are identified under Step 1, an analysis is conducted to eliminate technically infeasible options. A control option is eliminated from consideration if there are process-specific conditions that prohibit the implementation of the control technology.

### 2.1.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

In Step 3, remaining control technology options are ranked based on their control effectiveness, from highest to lowest control efficiency. This list must identify, at a minimum, the baseline emissions of $NO_X$ before implementation of each control option, the estimated reduction potential or control efficiency of each control option, and the estimated emissions after the application of each control option and the economic impacts.

### 2.1.4 Step 4: Evaluate Most Effective Controls and Document Results

Beginning with the highest-ranked control technology option from Step 3, detailed economic, energy, and environmental impact evaluations are performed in Step 4. If a control option is determined to be economically feasible without adverse energy or environmental impacts, it is not necessary to evaluate the remaining options with lower control efficiencies.

#### *2.1.4.1 Cost Analysis Methodology: Capital Costs*

The economic evaluation centers on the cost effectiveness of the control option. Costs of installing and operating control technologies are estimated and annualized following the methodologies outlined in the U.S. Environmental Protection Agency's (EPA's) Office of Air Quality Planning and Standards (OAQPS)

Control Cost Manual (CCM) and other industry resources. Based on the CCM, capital costs are annualized over a 15-year lifespan of the control equipment.[2]

### *2.1.4.2 Cost Analysis Methodology: Emissions*

Annualized costs are then converted to a dollar per ton of pollutant removed cost effectiveness value to determine whether a control technology is economically feasible. In the original alternative RACT analysis, CPP utilized annual average actual emissions from 2020 and 2021 for each boiler. The CPP, as part of its long-term strategic plan, took an important initial step in modernizing fuel combustion operations with the Cogeneration project. This project resulted in CPP voluntarily proposing and accepting an aggressive lower potential sitewide $NO_X$ limit of 196.7 tons per year (tpy) via a sitewide $NO_x$ PAL permit.[3] The permit action reduced sitewide potential emissions from CPP by approximately 81%.

It should also be noted that the base steam load of the AOC campus is served by the Cogeneration System which meets the presumptive RACT limits. Boilers 3 through 7, which are equipped with low $NO_X$ burners, are used to meet steam demands above the Cogeneration Plant capacity and to provide redundancy if Cogeneration Plant operation is interrupted. Frequently, the five (5) boilers are operating in low-fire while the combustion turbine is operating. The annual load factor of each boiler is less than 15%. Additionally, the five (5) boilers have been in operation for 60 years. By part loading multiple boilers, the furnace exit temperatures are reduced which contributes to the extended longevity of the units and reduces $NO_X$ formation.

DOEE clarified in the June 23, 2023 proposal that the District would be basing alternative RACT cost effectiveness on allowable emissions. CPP has updated the analyses presented in this updated report to use allowable emissions that align with our comments on DOEE's proposed determination. However, cost effectiveness calculations using actual emissions have been included as Appendix F for comparison purposes. These calculations demonstrate that the cost effectiveness for actual $NO_X$ that would not be emitted to the atmosphere is significantly higher than those based on allowable emissions, further demonstrating the cost ineffectiveness of add-on controls for these boilers.

### *2.1.4.3 Evaluating Economic Feasibility*

Cost effectiveness values, in dollars per ton of $NO_X$ removed, are then reviewed to determine if each control technology is cost effective. DOEE has not established a clear threshold to define acceptable cost effectiveness for RACT. However, in the June 23, 2023 proposal, DOEE references the thresholds for five (5) other states with an average cost effectiveness threshold of $7,150/ton.[4] CPP has utilized this threshold to determine cost effectiveness in this updated analysis. If the control technology with the highest control

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[2] CPP's original alternative RACT plan used a 20-year lifespan of control equipment and noted "that this is conservative for CPP's alternate RACT analysis as the boilers are likely to be replaced during this timeframe. According to the CPP's latest Master Utility Plan, these boilers are anticipated to be replaced in five to ten years which would further increase annualized costs as any control technology will only be used for the remainder of each boiler's operating life." In DOEE's June 23, 2023 proposal, DOEE has proposed to align our cost efficectiveness calculations with the CPP Master Utility Plan objectives and such that it is also consistent with the evaluation of similar alternative $NO_x$ RACT cost effectiveness analysis under review by DOEE. For example, Georgetown University used a 15-year lifespan of control equipment citing "A longer equipment life is unreasonable given boiler age." Given the similar situation, CPP has likewise determined use of 15 years is appropriate and updated the prior conservative assumption.

[3] Permit No. 6577 issued by DOEE with an effective date of June 6, 2013. The CPP also operates under a PAL of 248.1 tpy of $NO_X$ in Permit No. EPA-R3-PAL-001 issued by the U.S. EPA with an effective date of January 23, 2013.

[4] Table 3 of DOEE's June 23, 2023 Alternative $NO_X$ RACT proposal.

efficiency is not cost effective, it is eliminated and the next highest ranked technology from step 3 is evaluated for cost until a cost-effective technology is found or all technologies are eliminated.

### 2.1.5 Step 5: Select RACT

Using the result of the prior steps to determine the appropriate control technology, the final step is to determine the emission limit that represents the RACT limit.

## 2.2 $NO_X$ RACT Assessment for Boiler 3 (CU-3)

Boiler 3 is a 203 MMBtu/hr Wickes boiler that is permitted to operate on either fuel oil or natural gas. Boiler 3 has been in service for over 70 years and is a converted stoker fired coal boiler. Because of the furnace geometry, four (4) burners in a single row were installed to obtain the unit steam output. All four (4) burners utilize low $NO_X$ burner technology. The boiler design includes a flue gas feedwater economizer. Emissions from Boiler 3 are combined with emissions from Boilers 4 through 7 before venting to the atmosphere from the West Stack.

There are three (3) types of chemical kinetic processes that form $NO_X$ emissions from boilers referred to as: 1) thermal $NO_X$, 2) fuel $NO_X$, and 3) prompt $NO_X$. Thermal $NO_X$ is generated by the oxidation of molecular nitrogen ($N_2$) in the combustion air as it passes through the flame in the boiler. This reaction requires high temperatures, hence the name thermal $NO_X$. The formation of nitrogen oxide (NO) from oxygen ($O_2$) and $N_2$ in air at high temperatures is described by the well-known Zeldovich mechanism. Fuel $NO_X$ is the result of the conversion of nitrogen compounds contained in fuels to $NO_X$ during fuel combustion. Prompt $NO_X$ is formed by a combination of reactions between nitrogen, oxygen, and hydrocarbon radicals and is mostly significant in low-temperature, fuel-rich conditions where residence times are short.

### 2.2.1 Step 1: Identify All Control Technologies for $NO_X$

Step 1 in a top-down analysis is to identify all available control technologies. The evaluation of potential controls for $NO_X$ emissions includes both an investigation of end-of-pipe (post-combustion methods) which control all forms of $NO_X$ and combustion modifications/optimization that reduce the formation of thermal $NO_X$. Table 2-1 contains a list of the various technologies that have been evaluated for the control of $NO_X$ from Boiler 3 per 20 DCMR 805.2(c)(2) and each is further discussed below.

**Table 2-1. Potentially Available $NO_X$ Control Technologies for Boiler 3**

| Potentially Available $NO_X$ Control Technologies |
|---|
| SNCR |
| SCR |
| OFA |
| BOOS |
| LNB |
| FGR |

#### *2.2.1.1 SNCR*

SNCR is a post-combustion emissions control technology which involves injection of an ammonia-type reagent (typically ammonia or urea) into the furnace. The ammonia ($NH_3$) or a urea solution is injected into the gas stream to chemically reduce $NO_X$ to form $N_2$ and water. High temperatures, optimally between 1,600 to 2,000 degrees Fahrenheit (°F) for ammonia injection and 1,650 to 2,100 °F for urea injection, promote the reaction via the following equation: [5]

$$NH_3 + NO + {}^{1}/_{4}\,O_2 \rightarrow N_2 + {}^{3}/_{4}\,H_2O$$

#### *2.2.1.2 SCR*

SCR is an exhaust gas treatment process in which $NH_3$ is injected into the exhaust gas upstream of a catalyst bed. On the catalyst surface, $NH_3$, NO, and $NO_2$ react to form water and $N_2$ in the same reaction as for SNCR technology. The presence of the catalyst promotes this reaction at a much lower temperature than that required for SNCR, typically between 480 and 800 °F.[6]

#### *2.2.1.3 OFA*

OFA is a type of staged combustion control, wherein the amount of combustion air introduced into the burner zone is limited. Additional combustion air is introduced after the burner zone through OFA ports. By spreading out the combustion, oxygen concentrations are limited in the lower portions of the boiler, thereby limiting the oxidation of fuel-bound nitrogen and the formation of fuel $NO_X$.

#### *2.2.1.4 BOOS*

BOOS is a staged combustion technique which involves introducing additional natural gas at lower zones (fuel-rich zone) and additional air through registers of non-operating burners at higher zones to complete combustion. Note that by taking burners out of service the overall capacity of the emission unit is reduced.

#### *2.2.1.5 LNBs*

The principle of all LNBs is the same: stepwise or staged combustion and localized exhaust gas recirculation at the flame. LNBs are designed to control fuel and air mixing to create larger and more branched flames. Peak flame temperatures are reduced, resulting in less $NO_X$ formation. For boilers like those at CPP, a LNB is commonly combined with FGR technology to obtain a vendor guarantee that meets enforceable limitations.

#### *2.2.1.6 FGR*

With this technology, cooled flue gas is recirculated back in with the combustion air and thus reduces the combustion temperature by lowering the oxygen content of the mix and absorbing heat from the flame. The lower temperature lowers the amount of thermal $NO_X$ that is created. For boilers like those at CPP, FGR is commonly combined with LNB technology to obtain a vendor guarantee that meets enforceable limitations.

### 2.2.2 Step 2: Eliminate Technically Infeasible Options for $NO_X$ Control

Step 2 in a RACT top-down analysis is to eliminate the control options identified in Step 1 which are technically infeasible. The remaining technologies are then carried into Step 3.

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[5] Air Pollution Control Cost Manual, Section 4, Chapter 1, Selective Non-Catalytic Reduction, $NO_X$ Control, April 2019, Pages 1-9 to 1-11.

[6] Air Pollution Control Cost Manual, Section 4, Chapter 2, Selective Catalytic Reduction, $NO_X$ Control, June 2019, Section 2.2.2.

#### *2.2.2.1 SNCR*

SNCR requires a high but very specific temperature range (generally between 1,600 and 2,100 °F) and residence time at this temperature to be effective. Boiler 3 operates with an exhaust temperature below 300 °F.

Due to the low exhaust temperature, SNCR is a technically infeasible control technology and therefore is not RACT. Further evaluation of the technology is not required. However, in anticipation of questions from DOEE, CPP provided a cost effectiveness evaluation in the original alternative RACT plan to demonstrate that SNCR is both technically and economically infeasible for Boiler 3. DOEE's June 23, 2023 proposal accepted that SNCR is not technically feasible. For completeness, the cost effectiveness calculations are provided again in Appendix D but have not been updated.

#### *2.2.2.2 SCR*

The SCR process is temperature sensitive. Any exhaust gas temperature fluctuation reduces removal efficiency and upsets the $NH_3/NO_X$ molar ratio. SCR also requires an optimum temperature range of 480 to 800 °F and fairly constant temperatures, or $NO_X$ removal efficiency will decrease.[7] As stated above, Boiler 3 operates with an exhaust temperature below 300 °F.

Therefore, SCR would be ineffective at controlling $NO_X$ emissions and is not RACT. Further evaluation of the technology is not required. However, in anticipation of questions from DOEE, CPP provided a cost effectiveness evaluation in the original alternative RACT plan to demonstrate that SCR is both technically and economically infeasible for Boiler 3. DOEE's June 23, 2023 proposal accepted that SCR is not technically feasible. For completeness, the cost effectiveness calculations are provided again in Appendix D but have not been updated.

#### *2.2.2.3 OFA*

Installing an overfire air system for $NO_X$ removal is not technically feasible for Boiler 3. Due to the capacity of the boiler, the fuels utilized, and the existing low $NO_X$ burners, no additional $NO_X$ reduction is expected with this technology. Additionally, the physical configuration and age of the boiler make installation of OFA technically infeasible, and further evaluation of the technology is not required.

#### *2.2.2.4 BOOS*

Boiler 3 is a multiple burner unit with four (4) burners. As such, BOOS is evaluated for feasibility. Based on recent combustion analysis data for Boiler 3, there is no improvement in $NO_X$ formation whether the burners are operating at low or high loading. Boiler 3 currently operates near 50% of boiler design capacity, with all four (4) burners operating at roughly 50% capacity. BOOS at 50% design capacity could potentially have two (2) burners at 100% capacity, but BOOS applied to CPP would require three (3) burners at 66% capacity to meet the reliable steam output criteria of the plant [e.g., even with the loss of one (1) of the three (3) burners, the remaining two (2) burners could satisfy the output]. Additionally, the four (4) burners are in a flat configuration which is not beneficial for BOOS. The implementation of BOOS on Boiler 3 is not considered an applicable RACT $NO_X$ improvement method due to the demonstrated lack of $NO_X$ reduction that would result from the staging of linear configured burners as well as the fact that the existing burners are low $NO_X$ burners. A summary of the most recent combustion analysis data is provided in Appendix B, along with a chart of $NO_X$, CO, and excess air changes with changes in boiler output.

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[7] Air Pollution Control Cost Manual, Section 4, Chapter 2, Selective Catalytic Reduction, NOX Control, June 2019, Section 2.2.2.

For these reasons, BOOS is not considered to be technically feasible for controlling $NO_X$ emissions and is not RACT. Further evaluation of the technology is not required.

#### *2.2.2.5 LNBs*

Boiler 3 is equipped with LNB technology. Upon further evaluation with Affiliated Engineers, Inc. (AEI), the use of newer LNB technology to meet the presumptive RACT standards is technically infeasible without the addition of FGR.[8] The inability to obtain vendor guarantees at RACT levels by only applying LNB technology is uncertain at best. Therefore, in order to achieve the required $NO_X$ levels, FGR would be required. As such, only LNB with FGR is further evaluated. This determination is consistent with the two (2) other alternative RACT plans that DOEE has proposed to accept for similarly aged boilers.

#### *2.2.2.6 FGR*

FGR is a technically feasible option for lowering $NO_X$ emissions from Boiler 3. Since FGR would require replacement of the burners, more advanced LNB technology would be installed at the same time. The existing low $NO_X$ burners cannot be utilized with FGR. Replacing the burners with newer LNBs equipped with FGR is considered technically feasible and is therefore considered further in this analysis.

### 2.2.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

Step 3 in the top-down RACT analysis procedure is to rank remaining control technologies by control effectiveness. Table 2-2 compares the relative effectiveness of the technically feasible control technologies.

**Table 2-2. Ranking of Remaining Control Technologies for Boiler 3**

| Pollutant | Control Technology | Estimated $NO_X$ Emission Factor |
|---|---|---|
| $NO_X$ | LNB + FGR | 0.05 lb/MMBtu on gas<br>0.12 lb/MMBtu on oil |

### 2.2.4 Step 4: Evaluate Most Effective Controls and Document Results

In Step 4, the remaining control technologies, in order from most stringent control to least, are evaluated on the basis of economic, energy, and environmental considerations.

#### *2.2.4.1 LNBs with FGR*

Replacing all existing LNBs with new LNBs with FGR is the only technically feasible option for meeting the presumptive $NO_X$ emission limits.

Based on the presumptive $NO_X$ RACT limits and allowable emissions, the cost effectiveness for Boiler 3 is estimated to be $8,516 per ton of $NO_X$ removed. Accordingly, installation of LNBs with FGR on Boiler 3 is not considered an economically feasible option.

[8] July 6, 2023 email from Jack Ross, AEI, to Susan Barnes, Trinity Consultants.

Capital costs for this analysis were based on a site-specific engineering analysis and information from potential vendors (refer to Appendix E). The methodology and assumptions used to determine this cost effectiveness are presented in Appendix A.

### 2.2.5 Step 5: Select RACT

As RACT, CPP will continue to utilize the existing low $NO_X$ burners and to employ good combustion practices, proper boiler operation, and minimization of excess air. In addition, CPP will continue to comply with the existing fuel limitations for Boiler 3 of 748.80 million standard cubic feet (MMscf) of natural gas per year and 1,069,730 gallons of fuel oil per year.[9] CPP is also proposing to lower the emission limit for $NO_X$ from the current limit of 0.2 lb/MMBtu to 0.15 lb/MMBtu. Due to the combined stack configuration, CPP is proposing a single RACT limit for the West Stack of 0.15 lb/MMBtu. Refer to Section 2.4 for details of this proposed RACT emission limit.

## 2.3 $NO_X$ RACT Assessment for Boilers 4-7 (CU 4-7)

Boilers 4 through 7 are each 60 MMBtu/hr packaged watertube boilers that are permitted to operate on either fuel oil or natural gas. Each boiler is equipped with a single low $NO_X$ burner. Each has been in service for almost 60 years. Emissions from Boilers 4 through 7 are combined with emissions from Boiler 3 before venting to the atmosphere from the West Stack. Mechanisms for $NO_X$ production in Boilers 4 to 7 are the same as those in Boiler 3, refer to Section 2.2 for a detailed description.

### 2.3.1 Step 1: Identify All Control Technologies for $NO_X$

Step 1 in a top-down analysis is to identify all available control technologies. The evaluation of potential controls for $NO_X$ emissions includes both an investigation of end-of-pipe (post-combustion methods) and combustion modifications/optimization that reduce the formation of thermal $NO_X$. Table 2-3 contains a list of the various technologies that have been evaluated for the control of $NO_X$ from Boilers 4 through 7 per 20 DCMR 805.2(c)(2). Refer to Section 2.2.1 for descriptions of each control technology.

**Table 2-3. Potentially Available $NO_X$ Control Technologies for Boilers 4-7**

| Potentially Available $NO_X$ Control Technologies |
|---|
| SNCR |
| SCR |
| OFA |
| BOOS |
| LNB |
| FGR |

### 2.3.2 Step 2: Eliminate Technically Infeasible Options for $NO_X$ Control

Step 2 in a RACT top-down analysis is to eliminate the control options identified in Step 1 which are technically infeasible. The remaining technologies are then carried into Step 3.

[9] Permit No. 6576, Condition III.b

#### *2.3.2.1 SNCR*

SNCR requires a high but very specific temperature range (generally between 1,600 and 2,100 °F) and residence time at this temperature to be effective. Boilers 4 through 7 typically operate with exhaust temperatures of 300 to 600 °F based on available stack testing data.

Due to the low exhaust temperature, SNCR is considered a technically infeasible control technology and therefore is not RACT. Therefore, further evaluation of the technology is not required. However, in anticipation of questions from DOEE, CPP provided a cost effectiveness evaluation in the original alternative RACT plan to demonstrate that SNCR is both technically and economically infeasible for Boilers 4 through 7. DOEE's June 23, 2023 proposal accepted that SNCR is not technically feasible. For completeness, the cost effectiveness calculations are provided again in Appendix D but have not been updated.

#### *2.3.2.2 SCR*

The SCR process is temperature sensitive. Any exhaust gas temperature fluctuation reduces removal efficiency and upsets the $NH_3/NO_X$ molar ratio. SCR also requires an optimum temperature range of 480 to 800 °F and fairly constant temperatures, or $NO_X$ removal efficiency will decrease.[10] As stated above, Boilers 4 through 7 typically operate with exhaust temperatures of 300 to 600 °F based on available stack testing data.

Given this wide range of temperatures which are mostly below the optimum operating range of SCR, SCR is considered technically infeasible for Boilers 4 through 7 and is not RACT. Therefore, further evaluation of the technology is not required. However, in anticipation of questions from DOEE, CPP provided a cost effectiveness evaluation in the original alternative RACT plan to demonstrate that SCR is both technically and economically infeasible for Boilers 4 through 7. DOEE's June 23, 2023 proposal accepted that SCR is not technically feasible. For completeness, the cost effectiveness calculations are provided again in Appendix D but have not been updated.

#### *2.3.2.3 OFA*

Installing an overfire air system for $NO_X$ removal is not technically feasible for Boilers 4 through 7. Due to the capacity of the boilers, the fuels utilized, and the existing low $NO_X$ burners, no additional $NO_X$ reduction is expected with this technology. Additionally, the physical configuration and age of the boilers make installation of OFA technically infeasible, and further evaluation of the technology is not required.

#### *2.3.2.4 BOOS*

Boilers 4 through 7 are each configured with a single burner, meaning it is impossible to operate these boilers by taking a burner out of service. Therefore, BOOS is not technically feasible for controlling $NO_X$ emissions and is not RACT. Further evaluation of the technology is not required.

#### *2.3.2.5 LNBs*

Boilers 4 through 7 are equipped with LNB technology. Upon further evaluation with AEI, the use of newer LNB technology to meet the presumptive RACT standards is technically infeasible without adding FGR.[11] In

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[10] Air Pollution Control Cost Manual, Section 4, Chapter 2, Selective Catalytic Reduction, $NO_X$ Control, EPA/452/B-02-001, Page 2-9.

[11] July 6, 2023 email from Jack Ross, AEI, to Susan Barnes, Trinity Consultants.

order to achieve the required $NO_X$ levels, FGR would be required. As such, only LNB with FGR is further evaluated. This determination is consistent with the two (2) other alternative RACT plans that DOEE has proposed to accept for similarly aged boilers.

#### *2.3.2.6 FGR*

FGR is a technically feasible option for lowering $NO_X$ emissions from Boilers 4 through 7. Since FGR would require replacement of the burners, more advanced LNB technology would be installed at the same time. The existing low $NO_X$ burners cannot be utilized with FGR. Replacing the burners with newer LNBs equipped with FGR is considered technically feasible and is therefore considered further in this analysis.

### 2.3.3 Step 3: Rank Remaining Control Technologies by Control Effectiveness

Step 3 in the top-down RACT analysis procedure is to rank remaining control technologies by control effectiveness. Table 2-4 compares the relative effectiveness of the technically feasible control technologies.

**Table 2-4. Ranking of Remaining Control Technologies for Boilers 4-7**

| Pollutant | Control Technology | Estimated $NO_X$ Emission Factor |
|---|---|---|
| $NO_X$ | LNB + FGR | 0.05 lb/MMBtu on gas<br>0.09 lb/MMBtu on oil |

### 2.3.4 Step 4: Evaluate Most Effective Controls and Document Results

In Step 4, the remaining control technologies, in order from most stringent control to least, are evaluated on the basis of economic, energy, and environmental considerations.

#### *2.3.4.1 LNBs with FGR*

Replacing the existing LNBs with modern LNBs with FGR is the only technically feasible option for meeting the presumptive $NO_X$ emission limits.

Based on the presumptive $NO_X$ RACT limits and allowable emissions, the cost effectiveness of LNBs with FGR for Boilers 4 through 7 is estimated to be $13,461 per ton of $NO_X$ removed. Accordingly, installing modern LNBs with FGR on Boilers 4 through 7 is not a cost-effective option under RACT requirements.

Capital costs for this analysis were based on a site-specific engineering analysis and information from potential vendors (refer to Appendix E). The methodology and assumptions used to determine this cost effectiveness are presented in Appendix A.

### 2.3.5 Step 5: Select RACT

As RACT, CPP will continue to utilize the existing low $NO_X$ burners and to employ good combustion practices, proper boiler operation, and minimization of excess air. In addition, CPP is proposing a fuel usage limit of 408,000 MMBtu per year for each boiler. Boilers 4 through 7 are capable of burning either natural gas or fuel oil and currently have no restrictions on either fuel. In addition, CPP is proposing a $NO_X$ limit that will be independent of the fuel being used. As such, CPP is proposing a heat input limit in the form of MMBtu per year rather than proposing a traditional fuel usage limit. This will simplify monitoring requirements for demonstrating compliance with the proposed limits while maintaining the fuel flexibility needed to ensure

CPP continues to be able to meet steam demand regardless of fuel availability. If DOEE has concerns about the form of the proposed limit, CPP requests further discussions to arrive at a mutually agreeable limit.

CPP is also proposing to lower the emission limit for $NO_X$ from the current limit of 0.25 lb/MMBtu to 0.15 lb/MMBtu. Due to the combined stack configuration, CPP is proposing a single RACT limit for the West Stack of 0.15 lb/MMBtu. Refer to Section 2.4 for details of this proposed RACT emission limit.

## 2.4 Proposed RACT Emission Limit for West Stack

As discussed above, the five (5) boilers that exhaust to the West Stack are not currently capable of meeting the presumptive RACT limit and all possible control technologies are not technically feasible or not cost effective. Emissions to the West Stack are monitored using a single Continuous Emissions Monitoring System (CEMS) for $NO_X$. Nevertheless, CPP has reviewed what we believe to be an achievable $NO_x$ limitation for the remaining useful life of Boilers 3 through 7 and is proposing a more stringent limit for the West Stack of 0.15 lb/MMBtu on a 30-operating day rolling average.[12,13]

In addition to the proposed RACT limit, CPP will also continue to comply with $NO_X$ PALs for site-wide emissions including the boilers, and with $NO_X$ requirements in New Source Performance Standard (NSPS) Subpart Db for Boiler 3.

### 2.4.1 Suggested Additional Permit Conditions

As discussed above, CPP is proposing an emission limit for the West Stack along with operating limits for each boiler as alternative RACT for Boilers 3 through 7. The proposed permit conditions are provided below to clarify CPP's proposal:

- Combined emissions from Boilers 3 through 7 to the West Stack shall not exceed 0.15 lb/MMBtu on a 30-operating day rolling average basis as measured by a single CEMS.
- Boiler 3 fuel consumption shall be limited to 1,069,730 gallons of #2 fuel oil and 748.80 MMSCF of natural gas per year on a 12-month rolling basis.
- Boilers 4 through 7 fuel consumption shall each be limited to 408,000 MMBtu per boiler per year on a 12-month rolling basis, combined between heat input from natural gas and #2 fuel oil.

### 2.4.2 Compliance Timeline

Until DOEE provides a final determination on this alternative RACT plan, CPP will continue to comply with the $NO_x$ limitations in our existing Chapter 2 and Title V permits. In addition, we will keep records that support a compliance demonstration with our proposed limits if accepted by DOEE in a final alternative RACT determination.

[12] The current $NO_X$ emission limit is 0.2 lb/MMBtu for Boiler 3 and 0.25 lb/MMBtu for Boilers 4 through 7.

[13] To support this limit, CPP performed an upper prediction limit (UPL) calculation, consistent with EPA's methodology for setting emission limits for existing sources with monitoring data. Based on the UPL analysis using data from 2018 through 2021, an appropriate limit for the West Stack would be 0.22 lb/MMBtu. See Appendix C for additional information.

# APPENDIX A. DETAILED COST CALCULATIONS – ALLOWABLE EMISSIONS

This appendix contains detailed cost effectiveness calculations based on allowable emissions for:

- Installing LNBs with FGR on Boiler 3
- Installing LNBs with FGR on Boilers 4 through 7

***U.S. Capitol Power Plant***
***Boiler 3 (CU-3)***
***Cost Analysis for Reducing $NO_X$ Emissions by Installing Low $NO_X$ Burners (LNB) and Flue Gas Recirculation (FGR)***

| Cost Item | Computational Method | Cost | Notes |
|---|---|---|---|
| *Purchased Equipment Costs* | | | |
| Burner | | $1,100,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| FGR Fan | | $150,000 | |
| Total Equipment Costs | | $1,250,000 (A) | |
| *Direct Installation Costs* | | | |
| Burner Installation | | $80,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Front Wall Modifications | | $60,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Gas Piping | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Oil Piping | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Breaching | | $100,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Damper | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Wiring | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control/BMS Incorporation | | $60,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Electrical | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $460,000 (B) | |
| Total Purchased Equipment and Direct | (A + B) | $1,710,000 (C) | |
| *Indirect Installation Costs* | | | |
| Engineering | 0.10 (C) | $171,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction and Field Expenses | 0.04 (C) | $68,400 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contractor Fees | 0.10 (C) | $171,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Start-up | 0.02 (C) | $34,200 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contingencies | 0.03 (C) | $51,300 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $495,900 (D) | |
| *AOC Required Indirect Installation Costs* | | | |
| Contingency | 0.20 (C + D) | $441,180 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction Admin | 0.04 (C + D) | $88,236 | Project Cost Estimate Provided by AEI dated January 2022. |
| Government Test and QC | 0.025 (C + D) | $55,148 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC Construction Management | 0.20 (C + D) | $441,180 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC PM Fees | 0.05 (C + D) | $110,295 | Project Cost Estimate Provided by AEI dated January 2022. |
| Other | 0.05 (C + D) | $110,295 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $1,246,334 (E) | |
| **Total Installed Capital Cost** | (C + D + E) | $3,452,234 (F) | |
| *Direct Annual Costs* | | N/A | |
| *Indirect Annual Costs* | | | |
| Capital Recovery | CRF (F) | $343,931 (G) | Reference EPA CCM 6th Edition, Section 1, Chapter 2, Equation2.8a. CRF based on 15 years and 5.5% interest rate. |
| **Total Annualized Cost** | (G) | $343,931 | |
| *Cost Effectiveness* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 68.3 | Allowable emissions accounting for proposed NOx RACT limit of 0.15 lb/MMBtu and existing fuel usage limits |
| Max Heat Input on Gas (MMBtu/yr) | | 763,776 | Potential heat input based on 748.8 MMscf/yr limit and 1,020 Btu/scf |
| Controlled $NO_X$ Emissions Rate on Gas (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(2)(B)) |
| Max Heat Input on Oil (MMBtu/yr) | | 146,553 | Potential heat input based on 1,069,730 gal/yr limit and 0.137 MMBtu/gal |
| Controlled $NO_X$ Emissions Rate on Oil (lb/MMBtu) | | 0.12 | RACT limit for fuel oil (20 DCMR 805.5(e)(2)(A)) |
| Controlled $NO_X$ Emissions (tpy) | | 27.9 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 40.4 | |
| **Cost ($/ton $NO_X$ removed)** | | $8,516 | |

***U.S. Capitol Power Plant***
***Boiler 4, 5, 6, or 7 (CU-4, 5, 6, or 7)***
***Cost Analysis for Reducing $NO_X$ Emissions by Installing Low $NO_X$ Burners (LNB) and Flue Gas Recirculation (FGR)***

| Cost Item | Computational Method | Cost | Notes |
|---|---|---|---|
| *Purchased Equipment Costs* | | | |
| Burner | | $225,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| FGR Fan | | $25,000 | |
| Total Equipment Costs | | $250,000 (A) | |
| *Direct Installation Costs* | | | |
| Burner Installation | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Front Wall Modifications | | $30,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Gas Piping | | $10,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Oil Piping | | $10,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Breaching | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Damper | | $15,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Wiring | | $25,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control/BMS Incorporation | | $30,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Electrical | | $25,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $215,000 (B) | |
| Total Purchased Equipment and Direct | (A + B) | $465,000 (C) | |
| *Indirect Installation Costs* | | | |
| Engineering | 0.10 (C) | $46,500 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction and Field Expenses | 0.04 (C) | $18,600 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contractor Fees | 0.10 (C) | $46,500 | Project Cost Estimate Provided by AEI dated January 2022. |
| Start-up | 0.02 (C) | $9,300 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contingencies | 0.03 (C) | $13,950 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $134,850 (D) | |
| *AOC Required Indirect Installation Costs* | | | |
| Contingency | 0.20 (C + D) | $119,970 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction Admin | 0.04 (C + D) | $23,994 | Project Cost Estimate Provided by AEI dated January 2022. |
| Government Test and QC | 0.025 (C + D) | $14,996 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC Construction Management | 0.20 (C + D) | $119,970 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC PM Fees | 0.05 (C + D) | $29,993 | Project Cost Estimate Provided by AEI dated January 2022. |
| Other | 0.05 (C + D) | $29,993 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $338,915 (E) | |
| **Total Installed Capital Cost** | (C + D + E) | $938,765 (F) | |
| *Direct Annual Costs* | | N/A | |
| *Indirect Annual Costs* | | | |
| Capital Recovery | CRF (F) | $93,525 (G) | Reference EPA CCM 6th Edition, Section 1, Chapter 2, Equation2.8a. CRF based on 15 years and 5.5% interest rate. |
| **Total Annualized Cost** | (G) | $93,525 | |
| *Cost Effectiveness - Per Boiler* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 30.6 | Allowable emissions accounting for proposed NOx RACT limits of 0.15 lb/MMBtu and 408,000 MMBtu/yr per boiler |
| Max Heat Input (MMBtu/yr) | | 525,600 | Potential Heat Input (60 MMBtu/hr * 8760 hr/yr) |
| Controlled $NO_X$ Emissions Rate on Oil (lb/MMBtu) | | 0.09 | RACT limit for fuel oil (20 DCMR 805.5(e)(3)(A)) |
| Controlled $NO_X$ Emissions (tpy) | | 23.7 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 6.9 | |
| **Cost ($/ton $NO_X$ removed)** | | $13,461 | |

# APPENDIX B. BOILER 3 PERFORMANCE TEST DATA

**GAS Setting Data**

**Jobsite:** Architect of the Capital **Max Heat Input:** **Fired Vessel:** Hoffman Combustion Engineering

**ACE Project No.:** USC200221 **Unit capacity:** 180 kPPH **Burner:** _

**Date:** 12/3/2020

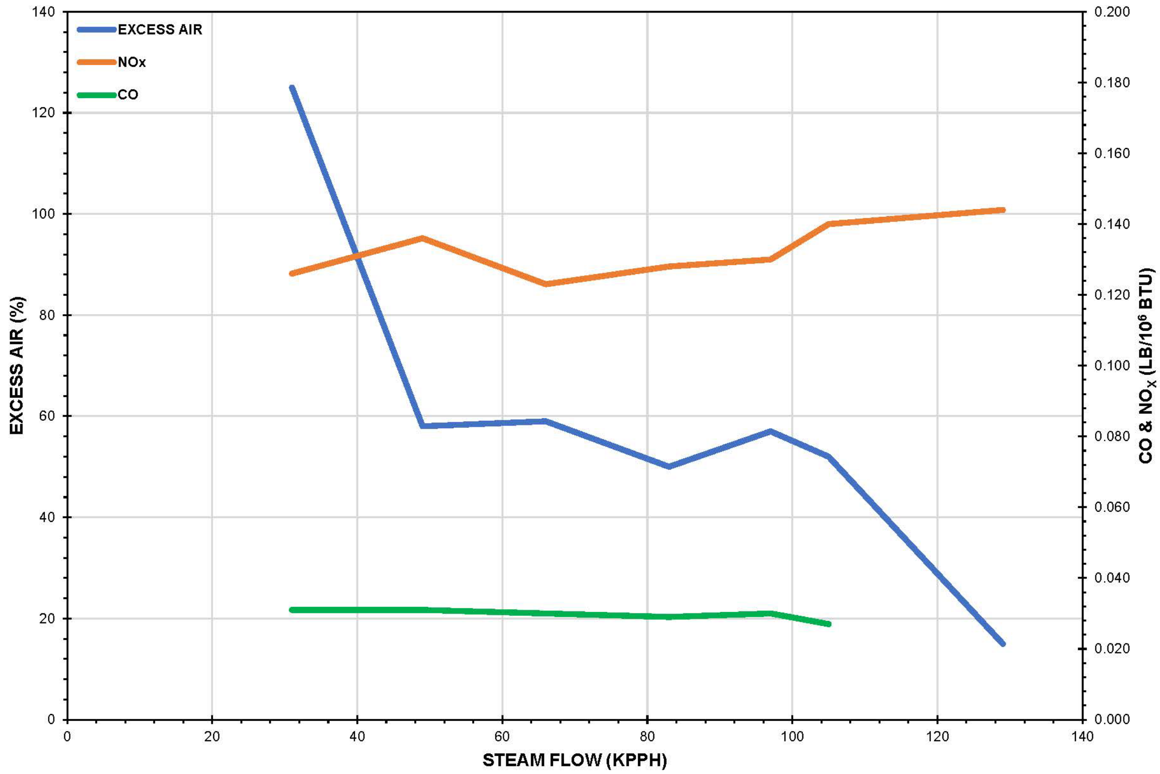
**AOC CPP BOILER No. 3**

**NOx Limit:** 0.2 #/mmbtu **Systems Engr.:** Paul Merluzzi

**Unit ID:** 3 **Fuel:** Natural Gas **Burner Tech:** Jim Bolton

Before After Before After Before After Before After Before After Before After Before After Before After

| Time (24 hr) | X | X | | 10:15 | | 10:39 | | 10:51 | | 11:06 | | 11:18 | | 11:33 | | 5:30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Curve Point | 0 | | 1 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 6 | 6 |
| Boiler Master output | 15 | | 20 | 20 | 30 | 30 | 40 | 40 | 50 | 50 | 60 | 60 | 70 | 70 | 80 | 80 |
| Gas Valve Pos. | 30 | | 33.6 | 33.2 | 39 | 39 | 44 | 45.5 | 51 | 51.3 | 57.5 | 56.2 | 61 | 63 | 61 | 67 |
| Windbox press., "w.c. | 0.38 | | 0.44 | 0.66 | 0.58 | 1.26 | 1.08 | 1.68 | 1.41 | 1.93 | 1.72 | 2.65 | 2.15 | 3.05 | 2.15 | 2.15 |
| *Furnace pressure., "wc* | -0.27 | | -0.19 | -0.21 | -0.18 | -0.15 | -0.12 | -0.13 | -0.18 | -0.31 | -0.23 | -0.14 | -0.16 | -0.3 | -0.16 | -0.16 |
| Throat DP | 0.65 | | 0.63 | 0.87 | 0.76 | 1.41 | 1.2 | 1.81 | 1.59 | 2.24 | 1.95 | 2.79 | 2.31 | 3.35 | 2.31 | 2.31 |
| Gas supply, psig | 18.36 | | 18.3 | 18.1 | 18.24 | 17.9 | 18.1 | 17.8 | 17.8 | 17.6 | 17.62 | 17.3 | 17.3 | 17 | 17.3 | 16.7 |
| Gas @ burner, psig | 0.15 | | 0.24 | 0.22 | 0.45 | 0.45 | 0.82 | 0.84 | 1.27 | 1.27 | 1.78 | 1.84 | 2.41 | 2.41 | 2.41 | 2.87 |
| Gas flow, kscfh | 30 | | 39 | 38 | 58 | 58 | 78 | 79 | 98 | 97 | 117 | 118 | 137 | 136 | 137 | 150 |
| FD Damper | 42 | | 42 | 41 | 43.6 | 46 | 52 | 53 | 58 | 57 | 64 | 64 | 71 | 70 | 71 | 98 |
| Burner 1 Register Setting | 2.5 | | 2.5 | 18 | 2.5 | 31.35 | 2.5 | 34.46 | 3 | 41.74 | 3 | 49.51 | 3.5 | 57.75 | 3.5 | 100 |
| Burner 2 Register Setting/Air Dampe | 3 | | 3 | 18 | 3.5 | 31.35 | 3.5 | 34.46 | 3.5 | 41.74 | 4.2 | 49.51 | 4.5 | 57.75 | 4.5 | 100 |
| Burner 3 Register Setting/Air Dampe | 3.5 | | 3.5 | 18 | 3.5 | 31.35 | 4 | 34.46 | 4.5 | 41.74 | 5 | 49.51 | 5.2 | 57.75 | 5.2 | 100 |
| Burner 4 Register Setting/Air Dampe | 2 | | 2 | 18 | 2.2 | 31.35 | 2.5 | 34.46 | 3 | 41.74 | 3 | 49.51 | 3.2 | 57.75 | 3.2 | 100 |
| ID Damper | 54 | | 48 | 57 | 61.3 | 67 | 75.3 | 77 | 79 | 74 | 77.5 | 78 | 79 | 78 | 79 | 89.4 |
| ID Fan RPM | 461 | | 413 | 421 | 406 | 400 | 437 | 433 | 487 | 535 | 618 | 628 | 707 | 724 | 707 | 824 |
| Steam Pressure, psig | 188 | | 189 | 188.85 | 189 | 190 | 193 | 193.5 | 192 | 198.3 | 196 | 198.15 | 206 | 207.3 | 206 | 182.05 |
| Steam flow, kpph | 24 | | 33 | 31 | 46 | 49 | 64 | 66 | 81 | 83 | 96 | 97 | 108 | 105 | 108 | 129 |
| Installed Stack Oxygen | 12.31 | | 9.7 | 7.9 | 5.21 | 6.1 | 5.02 | 5.2 | 3.96 | 3.8 | 3.64 | 3.4 | 3.41 | 3.3 | 3.41 | 5.6 |
| Combustion Air Flow, CFM | 10732 | | 10777 | 12575 | 11977 | 16793 | 16513 | 21235 | 19551 | 24043 | 22721 | 28816 | 26562 | 32880 | 26562 | 44097 |
| $O_2$ %, dry Testo | 12.68 | | 10.5 | 12 | 6.93 | 8.01 | 6.98 | 8.1 | 5.56 | 8 | 4.98 | 7.90 | 5.27 | 7.5 | 5.27 | 2.93 |
| NOx, ppm, raw Testo | 41.50 | | 58.90 | 51.90 | 89.90 | 80.90 | 85.50 | 72.60 | 97.70 | 76.50 | 100.30 | 78.40 | 106.30 | 86.90 | 106.30 | 119.50 |
| NO, ppm, raw Testo | 29.00 | | 56.00 | 49.00 | 87.00 | 78.00 | 83.00 | 70.00 | 95.00 | 74.00 | 98.00 | 76.00 | 104.00 | 85.00 | 104.00 | 117.00 |
| NO2, ppm, raw Testo | 12.5 | | 2.9 | 2.9 | 2.9 | 2.9 | 2.5 | 2.6 | 2.7 | 2.5 | 2.3 | 2.4 | 2.3 | 1.9 | 2.3 | 2.5 |
| CO, ppm, raw Testo | 4 | | 0 | 21 | 0 | 30 | 0 | 29 | 0 | 28 | 0 | 30 | 0 | 27 | 0 | 0 |
| $CO_2$ %, dry Testo | 4.64 | | 5.85 | 4.87 | 7.84 | 6.92 | 7.81 | 6.7 | 8.6 | 7.2 | 8.93 | 7.2 | 8.76 | 7.3 | 8.76 | 8.76 |
| *Excess air, % *** | 142.97 | | 93.83 | 125.09 | 46.23 | 57.87 | 46.72 | 58.93 | 33.80 | 57.75 | 29.15 | 56.59 | 31.44 | 52.14 | 31.44 | 15.22 |
| *NOx, #/MMBtu *** | 0.109 | | 0.123 | 0.126 | 0.139 | 0.136 | 0.133 | 0.123 | 0.138 | 0.128 | 0.136 | 0.130 | 0.147 | 0.140 | 0.147 | 0.144 |
| *CO, #/MMBtu *** | 0.006 | | 0.000 | 0.031 | 0.000 | 0.031 | 0.000 | 0.030 | 0.000 | 0.029 | 0.000 | 0.030 | 0.000 | 0.027 | 0.000 | 0.000 |
| Efficiency | 80.0 | | 78.0 | 83.4 | 78.0 | 85.3 | 77.0 | 85.2 | 79.0 | 85.2 | 79.0 | 85.0 | 77.0 | 84.8 | 77.0 | 76.0 |
| Econ Inlet Temp., Deg. F | 397.0 | | 400.8 | 386.0 | 410.0 | 396.0 | 434.0 | 419.0 | 460.0 | 450.0 | 493.0 | 484.0 | 524.0 | 505.0 | 524.0 | 551.0 |
| Econ Out Temp., Deg. F | 192.0 | | 191.0 | 227.0 | 190.5 | 219.0 | 177.0 | 217.0 | 178.0 | 218.0 | 184.0 | 223.0 | 191.0 | 227.0 | 191.0 | 239.0 |
| Stack Temperature, Deg F | | | | 272 | | 271 | | 279 | | 289 | | 303 | | 313 | | |
| Comb. air temp, deg F | 64 | | 64 | 64 | 64 | 64 | 63 | 63 | 63 | 63 | 62 | 62 | 61 | 61 | 61 | 61 |
| FW Flow GPM | 43 | | 78 | 68 | 124 | 123 | 149 | 139 | 195 | 164 | 208 | 209 | 236 | 218 | 236 | 245 |
| FW Flow KPPH | 21.5 | | 39 | 34 | 62 | 61.5 | 74.5 | 69.5 | 97.5 | 82 | 104 | 104.5 | 118 | 109 | 118 | 122.5 |
| O2 Trim % | 50.0% | | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% | 50.0% |
| FW Inlet Temp. to Econ | 233 | | 233.0 | 233.0 | 233.0 | 233.0 | 233.0 | 233.0 | 234.0 | 234.0 | 234.0 | 234.0 | 233.0 | 233.0 | 233.0 | 233.0 |
| Opacity. % | 5.2 | | 5.1 | 4.2 | 5.7 | 4.1 | 5.4 | 3.9 | 4.9 | 3.9 | 5.1 | 4.0 | 5.3 | 4.3 | 5.3 | 5.8 |



EXCESS AIR
NOx
CO
140
120
100
80
60
40
20
0
EXCESS AIR (%)
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
CO & NOX (LB/10⁶ BTU)
0
20
40
60
80
100
120
140
STEAM FLOW (KPPH)

# APPENDIX C. UPL CALCULATIONS

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 1/1/2019 | 0.107 | -2.2349 |
| 1/2/2019 | 0.109 | -2.2164 |
| 1/3/2019 | 0.109 | -2.2164 |
| 1/4/2019 | 0.108 | -2.2256 |
| 1/5/2019 | 0.107 | -2.2349 |
| 1/6/2019 | 0.113 | -2.1804 |
| 1/7/2019 | 0.112 | -2.1893 |
| 1/8/2019 | 0.104 | -2.2634 |
| 1/9/2019 | 0.115 | -2.1628 |
| 1/10/2019 | 0.114 | -2.1716 |
| 1/11/2019 | 0.116 | -2.1542 |
| 1/12/2019 | 0.116 | -2.1542 |
| 1/13/2019 | 0.114 | -2.1716 |
| 1/14/2019 | 0.114 | -2.1716 |
| 1/15/2019 | 0.116 | -2.1542 |
| 1/16/2019 | 0.114 | -2.1716 |
| 1/17/2019 | 0.115 | -2.1628 |
| 1/18/2019 | 0.113 | -2.1804 |
| 1/19/2019 | 0.114 | -2.1716 |
| 1/20/2019 | 0.113 | -2.1804 |
| 1/21/2019 | 0.116 | -2.1542 |
| 1/22/2019 | 0.12 | -2.1203 |
| 1/23/2019 | 0.118 | -2.1371 |
| 1/24/2019 | 0.109 | -2.2164 |
| 1/25/2019 | 0.117 | -2.1456 |
| 1/26/2019 | 0.117 | -2.1456 |
| 1/27/2019 | 0.121 | -2.1120 |
| 1/28/2019 | 0.121 | -2.1120 |
| 1/29/2019 | 0.120 | -2.1203 |
| 1/30/2019 | 0.120 | -2.1203 |
| 1/31/2019 | 0.121 | -2.1120 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 2/1/2019 | 0.118 | -2.1371 |
| 2/2/2019 | 0.118 | -2.1371 |
| 2/3/2019 | 0.117 | -2.1456 |
| 2/4/2019 | 0.114 | -2.1716 |
| 2/5/2019 | 0.111 | -2.1982 |
| 2/6/2019 | 0.113 | -2.1804 |
| 2/7/2019 | 0.111 | -2.1982 |
| 2/8/2019 | 0.114 | -2.1716 |
| 2/9/2019 | 0.122 | -2.1037 |
| 2/10/2019 | 0.118 | -2.1371 |
| 2/11/2019 | 0.113 | -2.1804 |
| 2/12/2019 | 0.114 | -2.1716 |
| 2/13/2019 | 0.116 | -2.1542 |
| 2/14/2019 | 0.117 | -2.1456 |
| 2/15/2019 | 0.118 | -2.1371 |
| 2/16/2019 | 0.119 | -2.1286 |
| 2/17/2019 | 0.116 | -2.1542 |
| 2/18/2019 | 0.116 | -2.1542 |
| 2/19/2019 | 0.119 | -2.1286 |
| 2/20/2019 | 0.115 | -2.1628 |
| 2/21/2019 | 0.115 | -2.1628 |
| 2/22/2019 | 0.119 | -2.1286 |
| 2/23/2019 | 0.118 | -2.1371 |
| 2/24/2019 | 0.116 | -2.1542 |
| 2/25/2019 | 0.121 | -2.1120 |
| 2/26/2019 | 0.122 | -2.1037 |
| 2/27/2019 | 0.118 | -2.1371 |
| 2/28/2019 | 0.119 | -2.1286 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 3/1/2019 | 0.117 | -2.1456 |
| 3/2/2019 | 0.114 | -2.1716 |
| 3/3/2019 | 0.118 | -2.1371 |
| 3/4/2019 | 0.119 | -2.1286 |
| 3/5/2019 | 0.122 | -2.1037 |
| 3/6/2019 | 0.123 | -2.0956 |
| 3/7/2019 | 0.123 | -2.0956 |
| 3/8/2019 | 0.118 | -2.1371 |
| 3/9/2019 | 0.119 | -2.1286 |
| 3/10/2019 | 0.112 | -2.1893 |
| 3/11/2019 | 0.117 | -2.1456 |
| 3/12/2019 | 0.118 | -2.1371 |
| 3/13/2019 | 0.117 | -2.1456 |
| 3/14/2019 | 0.114 | -2.1716 |
| 3/15/2019 | 0.107 | -2.2349 |
| 3/16/2019 | 0.119 | -2.1286 |
| 3/17/2019 | 0.119 | -2.1286 |
| 3/18/2019 | 0.118 | -2.1371 |
| 3/19/2019 | 0.12 | -2.1203 |
| 3/20/2019 | 0.119 | -2.1286 |
| 3/21/2019 | 0.111 | -2.1982 |
| 3/22/2019 | 0.113 | -2.1804 |
| 3/23/2019 | 0.12 | -2.1203 |
| 3/24/2019 | 0.121 | -2.1120 |
| 3/25/2019 | 0.112 | -2.1893 |
| 3/26/2019 | 0.117 | -2.1456 |
| 3/27/2019 | 0.119 | -2.1286 |
| 3/28/2019 | 0.114 | -2.1716 |
| 3/29/2019 | 0.105 | -2.2538 |
| 3/30/2019 | 0.114 | -2.1716 |
| 3/31/2019 | 0.115 | -2.1628 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 4/1/2019 | 0.122 | -2.1037 |
| 4/2/2019 | 0.12 | -2.1203 |
| 4/3/2019 | 0.121 | -2.1120 |
| 4/4/2019 | 0.119 | -2.1286 |
| 4/5/2019 | 0.113 | -2.1804 |
| 4/6/2019 | 0.112 | -2.1893 |
| 4/7/2019 | 0.108 | -2.2256 |
| 4/8/2019 | 0.101 | -2.2926 |
| 4/9/2019 | 0.104 | -2.2634 |
| 4/10/2019 | 0.115 | -2.1628 |
| 4/11/2019 | 0.108 | -2.2256 |
| 4/12/2019 | 0.1 | -2.3026 |
| 4/13/2019 | 0.096 | -2.3434 |
| 4/14/2019 | 0.094 | -2.3645 |
| 4/15/2019 | 0.105 | -2.2538 |
| 4/16/2019 | 0.116 | -2.1542 |
| 4/17/2019 | 0.108 | -2.2256 |
| 4/18/2019 | 0.104 | -2.2634 |
| 4/19/2019 | 0.093 | -2.3752 |
| 4/20/2019 | 0.1 | -2.3026 |
| 4/21/2019 | 0.105 | -2.2538 |
| 4/22/2019 | 0.105 | -2.2538 |
| 4/23/2019 | 0.106 | -2.2443 |
| 4/24/2019 | 0.108 | -2.2256 |
| 4/25/2019 | 0.108 | -2.2256 |
| 4/26/2019 | 0.099 | -2.3126 |
| 4/27/2019 | 0.113 | -2.1804 |
| 4/28/2019 | 0.106 | -2.2443 |
| 4/29/2019 | 0.109 | -2.2164 |
| 4/30/2019 | 0.1 | -2.3026 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 5/1/2019 | 0.1 | -2.3026 |
| 5/2/2019 | 0.094 | -2.3645 |
| 5/3/2019 | 0.089 | -2.4191 |
| 5/4/2019 | 0.094 | -2.3645 |
| 5/5/2019 | 0.094 | -2.3645 |
| 5/6/2019 | 0.1 | -2.3026 |
| 5/7/2019 | 0.096 | -2.3434 |
| 5/8/2019 | 0.097 | -2.3330 |
| 5/9/2019 | 0.096 | -2.3434 |
| 5/10/2019 | 0.094 | -2.3645 |
| 5/11/2019 | 0.098 | -2.3228 |
| 5/12/2019 | 0.099 | -2.3126 |
| 5/13/2019 | 0.104 | -2.2634 |
| 5/14/2019 | 0.105 | -2.2538 |
| 5/15/2019 | 0.104 | -2.2634 |
| 5/16/2019 | 0.099 | -2.3126 |
| 5/17/2019 | 0.094 | -2.3645 |
| 5/18/2019 | 0.093 | -2.3752 |
| 5/19/2019 | 0.092 | -2.3860 |
| 5/20/2019 | 0.098 | -2.3228 |
| 5/21/2019 | 0.105 | -2.2538 |
| 5/22/2019 | 0.105 | -2.2538 |
| 5/23/2019 | 0.094 | -2.3645 |
| 5/24/2019 | 0.098 | -2.3228 |
| 5/25/2019 | 0.092 | -2.3860 |
| 5/26/2019 | 0.087 | -2.4418 |
| 5/27/2019 | 0.091 | -2.3969 |
| 5/28/2019 | 0.086 | -2.4534 |
| 5/29/2019 | 0.084 | -2.4769 |
| 5/30/2019 | 0.088 | -2.4304 |
| 5/31/2019 | 0.091 | -2.3969 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 6/1/2019 | 0.095 | -2.3539 |
| 6/2/2019 | 0.09 | -2.4079 |
| 6/3/2019 | 0.104 | -2.2634 |
| 6/4/2019 | 0.106 | -2.2443 |
| 6/5/2019 | 0.089 | -2.4191 |
| 6/6/2019 | 0.085 | -2.4651 |
| 6/7/2019 | 0.087 | -2.4418 |
| 6/8/2019 | 0.096 | -2.3434 |
| 6/9/2019 | 0.092 | -2.3860 |
| 6/10/2019 | 0.088 | -2.4304 |
| 6/11/2019 | 0.097 | -2.3330 |
| 6/12/2019 | 0.098 | -2.3228 |
| 6/13/2019 | 0.091 | -2.3969 |
| 6/14/2019 | 0.102 | -2.2828 |
| 6/15/2019 | 0.098 | -2.3228 |
| 6/16/2019 | 0.09 | -2.4079 |
| 6/17/2019 | 0.086 | -2.4534 |
| 6/18/2019 | 0.085 | -2.4651 |
| 6/19/2019 | 0.084 | -2.4769 |
| 6/20/2019 | 0.087 | -2.4418 |
| 6/21/2019 | 0.092 | -2.3860 |
| 6/22/2019 | 0.088 | -2.4304 |
| 6/23/2019 | 0.083 | -2.4889 |
| 6/24/2019 | 0.078 | -2.5510 |
| 6/25/2019 | 0.075 | -2.5903 |
| 6/26/2019 | 0.084 | -2.4769 |
| 6/27/2019 | 0.087 | -2.4418 |
| 6/28/2019 | 0.086 | -2.4534 |
| 6/29/2019 | 0.086 | -2.4534 |
| 6/30/2019 | 0.091 | -2.3969 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 7/1/2019 | 0.09 | -2.4079 |
| 7/2/2019 | 0.063 | -2.7646 |
| 7/3/2019 | 0.024 | -3.7297 |
| 7/4/2019 | 0.016 | -4.1352 |
| 7/5/2019 | 0.018 | -4.0174 |
| 7/6/2019 | 0.021 | -3.8632 |
| 7/7/2019 | 0.029 | -3.5405 |
| 7/8/2019 | 0.024 | -3.7297 |
| 7/9/2019 | 0.018 | -4.0174 |
| 7/10/2019 | 0.02 | -3.9120 |
| 7/11/2019 | 0.022 | -3.8167 |
| 7/12/2019 | 0.027 | -3.6119 |
| 7/13/2019 | 0.022 | -3.8167 |
| 7/14/2019 | 0.023 | -3.7723 |
| 7/15/2019 | 0.049 | -3.0159 |
| 7/16/2019 | 0.065 | -2.7334 |
| 7/17/2019 | 0.049 | -3.0159 |
| 7/18/2019 | 0.026 | -3.6497 |
| 7/19/2019 | 0.039 | -3.2442 |
| 7/20/2019 | 0.018 | -4.0174 |
| 7/21/2019 | 0.029 | -3.5405 |
| 7/22/2019 | 0.02 | -3.9120 |
| 7/23/2019 | 0.023 | -3.7723 |
| 7/24/2019 | 0.019 | -3.9633 |
| 7/25/2019 | 0.024 | -3.7297 |
| 7/26/2019 | 0.038 | -3.2702 |
| 7/27/2019 | 0.043 | -3.1466 |
| 7/28/2019 | 0.039 | -3.2442 |
| 7/29/2019 | 0.042 | -3.1701 |
| 7/30/2019 | 0.065 | -2.7334 |
| 7/31/2019 | 0.063 | -2.7646 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 8/1/2019 | 0.062 | -2.7806 |
| 8/2/2019 | 0.056 | -2.8824 |
| 8/3/2019 | 0.025 | -3.6889 |
| 8/4/2019 | 0.024 | -3.7297 |
| 8/5/2019 | 0.029 | -3.5405 |
| 8/6/2019 | 0.031 | -3.4738 |
| 8/7/2019 | 0.047 | -3.0576 |
| 8/8/2019 | 0.049 | -3.0159 |
| 8/9/2019 | 0.036 | -3.3242 |
| 8/10/2019 | 0.034 | -3.3814 |
| 8/11/2019 | 0.055 | -2.9004 |
| 8/12/2019 | 0.042 | -3.1701 |
| 8/13/2019 | 0.022 | -3.8167 |
| 8/14/2019 | 0.028 | -3.5756 |
| 8/15/2019 | 0.03 | -3.5066 |
| 8/16/2019 | 0.049 | -3.0159 |
| 8/17/2019 | 0.024 | -3.7297 |
| 8/18/2019 | 0.029 | -3.5405 |
| 8/19/2019 | 0.031 | -3.4738 |
| 8/20/2019 | 0.055 | -2.9004 |
| 8/21/2019 | 0.037 | -3.2968 |
| 8/22/2019 | 0.039 | -3.2442 |
| 8/23/2019 | 0.02 | -3.9120 |
| 8/24/2019 | 0.022 | -3.8167 |
| 8/25/2019 | 0.051 | -2.9759 |
| 8/26/2019 | 0.053 | -2.9375 |
| 8/27/2019 | 0.08 | -2.5257 |
| 8/28/2019 | 0.075 | -2.5903 |
| 8/29/2019 | 0.083 | -2.4889 |
| 8/30/2019 | 0.08 | -2.5257 |
| 8/31/2019 | 0.079 | -2.5383 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 9/1/2019 | 0.039 | -3.2442 |
| 9/2/2019 | 0.053 | -2.9375 |
| 9/3/2019 | 0.032 | -3.4420 |
| 9/4/2019 | 0.027 | -3.6119 |
| 9/5/2019 | 0.092 | -2.3860 |
| 9/6/2019 | 0.134 | -2.0099 |
| 9/7/2019 | 0.132 | -2.0250 |
| 9/8/2019 | 0.137 | -1.9878 |
| 9/9/2019 | 0.139 | -1.9733 |
| 9/10/2019 | 0.133 | -2.0174 |
| 9/11/2019 | 0.126 | -2.0715 |
| 9/12/2019 | 0.121 | -2.1120 |
| 9/13/2019 | 0.12 | -2.1203 |
| 9/14/2019 | 0.117 | -2.1456 |
| 9/15/2019 | 0.12 | -2.1203 |
| 9/16/2019 | 0.118 | -2.1371 |
| 9/17/2019 | 0.115 | -2.1628 |
| 9/18/2019 | 0.129 | -2.0479 |
| 9/19/2019 | 0.134 | -2.0099 |
| 9/20/2019 | 0.108 | -2.2256 |
| 9/21/2019 | 0.085 | -2.4651 |
| 9/22/2019 | 0.082 | -2.5010 |
| 9/23/2019 | 0.088 | -2.4304 |
| 9/24/2019 | 0.091 | -2.3969 |
| 9/25/2019 | 0.1 | -2.3026 |
| 9/26/2019 | 0.097 | -2.3330 |
| 9/27/2019 | 0.097 | -2.3330 |
| 9/28/2019 | 0.088 | -2.4304 |
| 9/29/2019 | 0.089 | -2.4191 |
| 9/30/2019 | 0.094 | -2.3645 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 10/1/2019 | 0.093 | -2.3752 |
| 10/2/2019 | 0.089 | -2.4191 |
| 10/3/2019 | 0.089 | -2.4191 |
| 10/4/2019 | 0.1 | -2.3026 |
| 10/5/2019 | 0.102 | -2.2828 |
| 10/6/2019 | 0.092 | -2.3860 |
| 10/7/2019 | 0.095 | -2.3539 |
| 10/8/2019 | 0.103 | -2.2730 |
| 10/9/2019 | 0.102 | -2.2828 |
| 10/10/2019 | 0.103 | -2.2730 |
| 10/11/2019 | 0.107 | -2.2349 |
| 10/12/2019 | 0.101 | -2.2926 |
| 10/13/2019 | 0.103 | -2.2730 |
| 10/14/2019 | 0.099 | -2.3126 |
| 10/15/2019 | 0.096 | -2.3434 |
| 10/16/2019 | 0.092 | -2.3860 |
| 10/17/2019 | 0.098 | -2.3228 |
| 10/18/2019 | 0.098 | -2.3228 |
| 10/19/2019 | 0.097 | -2.3330 |
| 10/20/2019 | 0.091 | -2.3969 |
| 10/21/2019 | 0.096 | -2.3434 |
| 10/22/2019 | 0.088 | -2.4304 |
| 10/23/2019 | 0.099 | -2.3126 |
| 10/24/2019 | 0.101 | -2.2926 |
| 10/25/2019 | 0.098 | -2.3228 |
| 10/26/2019 | 0.1 | -2.3026 |
| 10/27/2019 | 0.097 | -2.3330 |
| 10/28/2019 | 0.099 | -2.3126 |
| 10/29/2019 | 0.093 | -2.3752 |
| 10/30/2019 | 0.092 | -2.3860 |
| 10/31/2019 | 0.087 | -2.4418 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 11/1/2019 | 0.108 | -2.2256 |
| 11/2/2019 | 0.108 | -2.2256 |
| 11/3/2019 | 0.106 | -2.2443 |
| 11/4/2019 | 0.107 | -2.2349 |
| 11/5/2019 | 0.105 | -2.2538 |
| 11/6/2019 | 0.106 | -2.2443 |
| 11/7/2019 | 0.103 | -2.2730 |
| 11/8/2019 | 0.113 | -2.1804 |
| 11/9/2019 | 0.114 | -2.1716 |
| 11/10/2019 | 0.109 | -2.2164 |
| 11/11/2019 | 0.108 | -2.2256 |
| 11/12/2019 | 0.11 | -2.2073 |
| 11/13/2019 | 0.118 | -2.1371 |
| 11/14/2019 | 0.115 | -2.1628 |
| 11/15/2019 | 0.105 | -2.2538 |
| 11/16/2019 | 0.113 | -2.1804 |
| 11/17/2019 | 0.117 | -2.1456 |
| 11/18/2019 | 0.111 | -2.1982 |
| 11/19/2019 | 0.11 | -2.2073 |
| 11/20/2019 | 0.112 | -2.1893 |
| 11/21/2019 | 0.113 | -2.1804 |
| 11/22/2019 | 0.109 | -2.2164 |
| 11/23/2019 | 0.112 | -2.1893 |
| 11/24/2019 | 0.112 | -2.1893 |
| 11/25/2019 | 0.113 | -2.1804 |
| 11/26/2019 | 0.11 | -2.2073 |
| 11/27/2019 | 0.108 | -2.2256 |
| 11/28/2019 | 0.114 | -2.1716 |
| 11/29/2019 | 0.117 | -2.1456 |
| 11/30/2019 | 0.117 | -2.1456 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 12/1/2019 | 0.111 | -2.1982 |
| 12/2/2019 | 0.111 | -2.1982 |
| 12/3/2019 | 0.115 | -2.1628 |
| 12/4/2019 | 0.113 | -2.1804 |
| 12/5/2019 | 0.116 | -2.1542 |
| 12/6/2019 | 0.115 | -2.1628 |
| 12/7/2019 | 0.118 | -2.1371 |
| 12/8/2019 | 0.115 | -2.1628 |
| 12/9/2019 | 0.109 | -2.2164 |
| 12/10/2019 | 0.104 | -2.2634 |
| 12/11/2019 | 0.115 | -2.1628 |
| 12/12/2019 | 0.117 | -2.1456 |
| 12/13/2019 | 0.111 | -2.1982 |
| 12/14/2019 | 0.109 | -2.2164 |
| 12/15/2019 | 0.113 | -2.1804 |
| 12/16/2019 | 0.112 | -2.1893 |
| 12/17/2019 | 0.113 | -2.1804 |
| 12/18/2019 | 0.117 | -2.1456 |
| 12/19/2019 | 0.118 | -2.1371 |
| 12/20/2019 | 0.116 | -2.1542 |
| 12/21/2019 | 0.116 | -2.1542 |
| 12/22/2019 | 0.116 | -2.1542 |
| 12/23/2019 | 0.114 | -2.1716 |
| 12/24/2019 | 0.114 | -2.1716 |
| 12/25/2019 | 0.113 | -2.1804 |
| 12/26/2019 | 0.111 | -2.1982 |
| 12/27/2019 | 0.107 | -2.2349 |
| 12/28/2019 | 0.109 | -2.2164 |
| 12/29/2019 | 0.106 | -2.2443 |
| 12/30/2019 | 0.102 | -2.2828 |
| 12/31/2019 | 0.111 | -2.1982 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 1/1/2020 | 0.114 | -2.1716 |
| 1/2/2020 | 0.115 | -2.1628 |
| 1/3/2020 | 0.106 | -2.2443 |
| 1/4/2020 | 0.105 | -2.2538 |
| 1/5/2020 | 0.114 | -2.1716 |
| 1/6/2020 | 0.114 | -2.1716 |
| 1/7/2020 | 0.112 | -2.1893 |
| 1/8/2020 | 0.116 | -2.1542 |
| 1/9/2020 | 0.115 | -2.1628 |
| 1/10/2020 | 0.111 | -2.1982 |
| 1/11/2020 | 0.101 | -2.2926 |
| 1/12/2020 | 0.102 | -2.2828 |
| 1/13/2020 | 0.108 | -2.2256 |
| 1/14/2020 | 0.107 | -2.2349 |
| 1/15/2020 | 0.106 | -2.2443 |
| 1/16/2020 | 0.11 | -2.2073 |
| 1/17/2020 | 0.11 | -2.2073 |
| 1/18/2020 | 0.114 | -2.1716 |
| 1/19/2020 | 0.111 | -2.1982 |
| 1/20/2020 | 0.112 | -2.1893 |
| 1/21/2020 | 0.113 | -2.1804 |
| 1/22/2020 | 0.116 | -2.1542 |
| 1/23/2020 | 0.116 | -2.1542 |
| 1/24/2020 | 0.114 | -2.1716 |
| 1/25/2020 | 0.106 | -2.2443 |
| 1/26/2020 | 0.11 | -2.2073 |
| 1/27/2020 | 0.109 | -2.2164 |
| 1/28/2020 | 0.109 | -2.2164 |
| 1/29/2020 | 0.112 | -2.1893 |
| 1/30/2020 | 0.114 | -2.1716 |
| 1/31/2020 | 0.11 | -2.2073 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 2/1/2020 | 0.109 | -2.2164 |
| 2/2/2020 | 0.109 | -2.2164 |
| 2/3/2020 | 0.109 | -2.2164 |
| 2/4/2020 | 0.103 | -2.2730 |
| 2/5/2020 | 0.103 | -2.2730 |
| 2/6/2020 | 0.105 | -2.2538 |
| 2/7/2020 | 0.104 | -2.2634 |
| 2/8/2020 | 0.111 | -2.1982 |
| 2/9/2020 | 0.110 | -2.2073 |
| 2/10/2020 | 0.105 | -2.2538 |
| 2/11/2020 | 0.101 | -2.2926 |
| 2/12/2020 | 0.108 | -2.2256 |
| 2/13/2020 | 0.102 | -2.2828 |
| 2/14/2020 | 0.109 | -2.2164 |
| 2/15/2020 | 0.113 | -2.1804 |
| 2/16/2020 | 0.115 | -2.1628 |
| 2/17/2020 | 0.113 | -2.1804 |
| 2/18/2020 | 0.109 | -2.2164 |
| 2/19/2020 | 0.111 | -2.1982 |
| 2/20/2020 | 0.113 | -2.1804 |
| 2/21/2020 | 0.115 | -2.1628 |
| 2/22/2020 | 0.115 | -2.1628 |
| 2/23/2020 | 0.114 | -2.1716 |
| 2/24/2020 | 0.112 | -2.1893 |
| 2/25/2020 | 0.104 | -2.2634 |
| 2/26/2020 | 0.103 | -2.2730 |
| 2/27/2020 | 0.112 | -2.1893 |
| 2/28/2020 | 0.112 | -2.1893 |
| 2/29/2020 | 0.111 | -2.1982 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 3/1/2020 | 0.114 | -2.1716 |
| 3/2/2020 | 0.111 | -2.1982 |
| 3/3/2020 | 0.104 | -2.2634 |
| 3/4/2020 | 0.111 | -2.1982 |
| 3/5/2020 | 0.113 | -2.1804 |
| 3/6/2020 | 0.111 | -2.1982 |
| 3/7/2020 | 0.115 | -2.1628 |
| 3/8/2020 | 0.114 | -2.1716 |
| 3/9/2020 | 0.111 | -2.1982 |
| 3/10/2020 | 0.097 | -2.3330 |
| 3/11/2020 | 0.105 | -2.2538 |
| 3/12/2020 | 0.106 | -2.2443 |
| 3/13/2020 | 0.108 | -2.2256 |
| 3/14/2020 | 0.113 | -2.1804 |
| 3/15/2020 | 0.106 | -2.2443 |
| 3/16/2020 | 0.107 | -2.2349 |
| 3/17/2020 | 0.104 | -2.2634 |
| 3/18/2020 | 0.107 | -2.2349 |
| 3/19/2020 | 0.096 | -2.3434 |
| 3/20/2020 | 0.095 | -2.3539 |
| 3/21/2020 | 0.101 | -2.2926 |
| 3/22/2020 | 0.105 | -2.2538 |
| 3/23/2020 | 0.102 | -2.2828 |
| 3/24/2020 | 0.104 | -2.2634 |
| 3/25/2020 | 0.103 | -2.2730 |
| 3/26/2020 | 0.103 | -2.2730 |
| 3/27/2020 | 0.102 | -2.2828 |
| 3/28/2020 | 0.097 | -2.3330 |
| 3/29/2020 | 0.099 | -2.3126 |
| 3/30/2020 | 0.105 | -2.2538 |
| 3/31/2020 | 0.105 | -2.2538 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 4/1/2020 | 0.105 | -2.2538 |
| 4/2/2020 | 0.11 | -2.2073 |
| 4/3/2020 | 0.109 | -2.2164 |
| 4/4/2020 | 0.103 | -2.2730 |
| 4/5/2020 | 0.101 | -2.2926 |
| 4/6/2020 | 0.104 | -2.2634 |
| 4/7/2020 | 0.099 | -2.3126 |
| 4/8/2020 | 0.099 | -2.3126 |
| 4/9/2020 | 0.103 | -2.2730 |
| 4/10/2020 | 0.109 | -2.2164 |
| 4/11/2020 | 0.11 | -2.2073 |
| 4/12/2020 | 0.101 | -2.2926 |
| 4/13/2020 | 0.096 | -2.3434 |
| 4/14/2020 | 0.108 | -2.2256 |
| 4/15/2020 | 0.109 | -2.2164 |
| 4/16/2020 | 0.111 | -2.1982 |
| 4/17/2020 | 0.109 | -2.2164 |
| 4/18/2020 | 0.106 | -2.2443 |
| 4/19/2020 | 0.108 | -2.2256 |
| 4/20/2020 | 0.104 | -2.2634 |
| 4/21/2020 | 0.105 | -2.2538 |
| 4/22/2020 | 0.112 | -2.1893 |
| 4/23/2020 | 0.104 | -2.2634 |
| 4/24/2020 | 0.099 | -2.3126 |
| 4/25/2020 | 0.102 | -2.2828 |
| 4/26/2020 | 0.1 | -2.3026 |
| 4/27/2020 | 0.104 | -2.2634 |
| 4/28/2020 | 0.104 | -2.2634 |
| 4/29/2020 | 0.103 | -2.2730 |
| 4/30/2020 | 0.098 | -2.3228 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 5/1/2020 | 0.113 | -2.1804 |
| 5/2/2020 | 0.102 | -2.2828 |
| 5/3/2020 | 0.094 | -2.3645 |
| 5/4/2020 | 0.093 | -2.3752 |
| 5/5/2020 | 0.1 | -2.3026 |
| 5/6/2020 | 0.113 | -2.1804 |
| 5/7/2020 | 0.109 | -2.2164 |
| 5/8/2020 | 0.111 | -2.1982 |
| 5/9/2020 | 0.11 | -2.2073 |
| 5/10/2020 | 0.11 | -2.2073 |
| 5/11/2020 | 0.114 | -2.1716 |
| 5/12/2020 | 0.114 | -2.1716 |
| 5/13/2020 | 0.116 | -2.1542 |
| 5/14/2020 | 0.114 | -2.1716 |
| 5/15/2020 | 0.113 | -2.1804 |
| 5/16/2020 | 0.107 | -2.2349 |
| 5/17/2020 | 0.107 | -2.2349 |
| 5/18/2020 | 0.108 | -2.2256 |
| 5/19/2020 | 0.11 | -2.2073 |
| 5/20/2020 | 0.109 | -2.2164 |
| 5/21/2020 | 0.114 | -2.1716 |
| 5/22/2020 | 0.104 | -2.2634 |
| 5/23/2020 | 0.104 | -2.2634 |
| 5/24/2020 | 0.101 | -2.2926 |
| 5/25/2020 | 0.099 | -2.3126 |
| 5/26/2020 | 0.096 | -2.3434 |
| 5/27/2020 | 0.093 | -2.3752 |
| 5/28/2020 | 0.1 | -2.3026 |
| 5/29/2020 | 0.093 | -2.3752 |
| 5/30/2020 | 0.095 | -2.3539 |
| 5/31/2020 | 0.098 | -2.3228 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 6/1/2020 | 0.105 | -2.2538 |
| 6/2/2020 | 0.098 | -2.3228 |
| 6/3/2020 | 0.089 | -2.4191 |
| 6/4/2020 | 0.087 | -2.4418 |
| 6/5/2020 | 0.087 | -2.4418 |
| 6/6/2020 | 0.093 | -2.3752 |
| 6/7/2020 | 0.104 | -2.2634 |
| 6/8/2020 | 0.105 | -2.2538 |
| 6/9/2020 | 0.093 | -2.3752 |
| 6/10/2020 | 0.087 | -2.4418 |
| 6/11/2020 | 0.092 | -2.3860 |
| 6/12/2020 | 0.105 | -2.2538 |
| 6/13/2020 | 0.106 | -2.2443 |
| 6/14/2020 | 0.105 | -2.2538 |
| 6/15/2020 | 0.104 | -2.2634 |
| 6/16/2020 | 0.104 | -2.2634 |
| 6/17/2020 | 0.096 | -2.3434 |
| 6/18/2020 | 0.094 | -2.3645 |
| 6/19/2020 | 0.093 | -2.3752 |
| 6/20/2020 | 0.091 | -2.3969 |
| 6/21/2020 | 0.092 | -2.3860 |
| 6/22/2020 | 0.092 | -2.3860 |
| 6/23/2020 | 0.091 | -2.3969 |
| 6/24/2020 | 0.097 | -2.3330 |
| 6/25/2020 | 0.095 | -2.3539 |
| 6/26/2020 | 0.097 | -2.3330 |
| 6/27/2020 | 0.09 | -2.4079 |
| 6/28/2020 | 0.09 | -2.4079 |
| 6/29/2020 | 0.094 | -2.3645 |
| 6/30/2020 | 0.096 | -2.3434 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 7/1/2020 | 0.091 | -2.3969 |
| 7/2/2020 | 0.095 | -2.3539 |
| 7/3/2020 | 0.095 | -2.3539 |
| 7/4/2020 | 0.093 | -2.3752 |
| 7/5/2020 | 0.087 | -2.4418 |
| 7/6/2020 | 0.088 | -2.4304 |
| 7/7/2020 | 0.089 | -2.4191 |
| 7/8/2020 | 0.091 | -2.3969 |
| 7/9/2020 | 0.088 | -2.4304 |
| 7/10/2020 | 0.087 | -2.4418 |
| 7/11/2020 | 0.091 | -2.3969 |
| 7/12/2020 | 0.094 | -2.3645 |
| 7/13/2020 | 0.094 | -2.3645 |
| 7/14/2020 | 0.098 | -2.3228 |
| 7/15/2020 | 0.098 | -2.3228 |
| 7/16/2020 | 0.117 | -2.1456 |
| 7/17/2020 | 0.094 | -2.3645 |
| 7/18/2020 | 0.111 | -2.1982 |
| 7/19/2020 | 0.104 | -2.2634 |
| 7/20/2020 | 0.101 | -2.2926 |
| 7/21/2020 | 0.103 | -2.2730 |
| 7/22/2020 | 0.091 | -2.3969 |
| 7/23/2020 | 0.035 | -3.3524 |
| 7/24/2020 | 0.03 | -3.5066 |
| 7/25/2020 | 0.028 | -3.5756 |
| 7/26/2020 | 0.033 | -3.4112 |
| 7/27/2020 | 0.028 | -3.5756 |
| 7/28/2020 | 0.042 | -3.1701 |
| 7/29/2020 | 0.046 | -3.0791 |
| 7/30/2020 | 0.043 | -3.1466 |
| 7/31/2020 | 0.035 | -3.3524 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 8/1/2020 | 0.026 | -3.6497 |
| 8/2/2020 | | |
| 8/3/2020 | | |
| 8/4/2020 | | |
| 8/5/2020 | | |
| 8/6/2020 | | |
| 8/7/2020 | 0.058 | -2.8473 |
| 8/8/2020 | 0.044 | -3.1236 |
| 8/9/2020 | 0.075 | -2.5903 |
| 8/10/2020 | 0.09 | -2.4079 |
| 8/11/2020 | 0.086 | -2.4534 |
| 8/12/2020 | 0.089 | -2.4191 |
| 8/13/2020 | 0.09 | -2.4079 |
| 8/14/2020 | 0.091 | -2.3969 |
| 8/15/2020 | 0.095 | -2.3539 |
| 8/16/2020 | 0.094 | -2.3645 |
| 8/17/2020 | 0.095 | -2.3539 |
| 8/18/2020 | 0.098 | -2.3228 |
| 8/19/2020 | 0.096 | -2.3434 |
| 8/20/2020 | 0.099 | -2.3126 |
| 8/21/2020 | 0.094 | -2.3645 |
| 8/22/2020 | 0.092 | -2.3860 |
| 8/23/2020 | 0.093 | -2.3752 |
| 8/24/2020 | 0.092 | -2.3860 |
| 8/25/2020 | 0.096 | -2.3434 |
| 8/26/2020 | 0.1 | -2.3026 |
| 8/27/2020 | 0.095 | -2.3539 |
| 8/28/2020 | 0.093 | -2.3752 |
| 8/29/2020 | 0.09 | -2.4079 |
| 8/30/2020 | 0.102 | -2.2828 |
| 8/31/2020 | 0.097 | -2.3330 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 9/1/2020 | 0.044 | -3.1236 |
| 9/2/2020 | 0.079 | -2.5383 |
| 9/3/2020 | 0.089 | -2.4191 |
| 9/4/2020 | 0.091 | -2.3969 |
| 9/5/2020 | 0.102 | -2.2828 |
| 9/6/2020 | 0.097 | -2.3330 |
| 9/7/2020 | 0.096 | -2.3434 |
| 9/8/2020 | 0.09 | -2.4079 |
| 9/9/2020 | 0.084 | -2.4769 |
| 9/10/2020 | 0.083 | -2.4889 |
| 9/11/2020 | 0.087 | -2.4418 |
| 9/12/2020 | 0.094 | -2.3645 |
| 9/13/2020 | 0.093 | -2.3752 |
| 9/14/2020 | 0.096 | -2.3434 |
| 9/15/2020 | 0.102 | -2.2828 |
| 9/16/2020 | 0.097 | -2.3330 |
| 9/17/2020 | 0.09 | -2.4079 |
| 9/18/2020 | 0.096 | -2.3434 |
| 9/19/2020 | 0.106 | -2.2443 |
| 9/20/2020 | 0.105 | -2.2538 |
| 9/21/2020 | 0.105 | -2.2538 |
| 9/22/2020 | 0.103 | -2.2730 |
| 9/23/2020 | 0.102 | -2.2828 |
| 9/24/2020 | 0.094 | -2.3645 |
| 9/25/2020 | 0.092 | -2.3860 |
| 9/26/2020 | 0.091 | -2.3969 |
| 9/27/2020 | 0.088 | -2.4304 |
| 9/28/2020 | 0.089 | -2.4191 |
| 9/29/2020 | 0.09 | -2.4079 |
| 9/30/2020 | 0.099 | -2.3126 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 10/1/2020 | 0.101 | -2.2926 |
| 10/2/2020 | 0.103 | -2.2730 |
| 10/3/2020 | 0.104 | -2.2634 |
| 10/4/2020 | 0.102 | -2.2828 |
| 10/5/2020 | 0.102 | -2.2828 |
| 10/6/2020 | 0.1 | -2.3026 |
| 10/7/2020 | 0.099 | -2.3126 |
| 10/8/2020 | 0.107 | -2.2349 |
| 10/9/2020 | 0.103 | -2.2730 |
| 10/10/2020 | 0.096 | -2.3434 |
| 10/11/2020 | 0.091 | -2.3969 |
| 10/12/2020 | 0.094 | -2.3645 |
| 10/13/2020 | 0.099 | -2.3126 |
| 10/14/2020 | 0.101 | -2.2926 |
| 10/15/2020 | 0.096 | -2.3434 |
| 10/16/2020 | 0.11 | -2.2073 |
| 10/17/2020 | 0.114 | -2.1716 |
| 10/18/2020 | 0.111 | -2.1982 |
| 10/19/2020 | 0.106 | -2.2443 |
| 10/20/2020 | 0.103 | -2.2730 |
| 10/21/2020 | 0.097 | -2.3330 |
| 10/22/2020 | 0.098 | -2.3228 |
| 10/23/2020 | 0.099 | -2.3126 |
| 10/24/2020 | 0.103 | -2.2730 |
| 10/25/2020 | 0.105 | -2.2538 |
| 10/26/2020 | 0.109 | -2.2164 |
| 10/27/2020 | 0.114 | -2.1716 |
| 10/28/2020 | 0.108 | -2.2256 |
| 10/29/2020 | 0.112 | -2.1893 |
| 10/30/2020 | 0.123 | -2.0956 |
| 10/31/2020 | 0.125 | -2.0794 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 11/1/2020 | 0.118 | -2.1371 |
| 11/2/2020 | 0.125 | -2.0794 |
| 11/3/2020 | 0.123 | -2.0956 |
| 11/4/2020 | 0.119 | -2.1286 |
| 11/5/2020 | 0.116 | -2.1542 |
| 11/6/2020 | 0.114 | -2.1716 |
| 11/7/2020 | 0.116 | -2.1542 |
| 11/8/2020 | 0.11 | -2.2073 |
| 11/9/2020 | 0.121 | -2.1120 |
| 11/10/2020 | 0.119 | -2.1286 |
| 11/11/2020 | 0.124 | -2.0875 |
| 11/12/2020 | 0.12 | -2.1203 |
| 11/13/2020 | 0.124 | -2.0875 |
| 11/14/2020 | 0.128 | -2.0557 |
| 11/15/2020 | 0.13 | -2.0402 |
| 11/16/2020 | 0.141 | -1.9590 |
| 11/17/2020 | 0.129 | -2.0479 |
| 11/18/2020 | 0.127 | -2.0636 |
| 11/19/2020 | 0.129 | -2.0479 |
| 11/20/2020 | 0.121 | -2.1120 |
| 11/21/2020 | 0.1 | -2.3026 |
| 11/22/2020 | 0.099 | -2.3126 |
| 11/23/2020 | 0.102 | -2.2828 |
| 11/24/2020 | 0.111 | -2.1982 |
| 11/25/2020 | 0.104 | -2.2634 |
| 11/26/2020 | 0.093 | -2.3752 |
| 11/27/2020 | 0.096 | -2.3434 |
| 11/28/2020 | 0.096 | -2.3434 |
| 11/29/2020 | 0.099 | -2.3126 |
| 11/30/2020 | 0.117 | -2.1456 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 12/1/2020 | 0.12 | -2.1203 |
| 12/2/2020 | 0.119 | -2.1286 |
| 12/3/2020 | 0.094 | -2.3645 |
| 12/4/2020 | 0.093 | -2.3752 |
| 12/5/2020 | 0.111 | -2.1982 |
| 12/6/2020 | 0.113 | -2.1804 |
| 12/7/2020 | 0.113 | -2.1804 |
| 12/8/2020 | 0.115 | -2.1628 |
| 12/9/2020 | 0.115 | -2.1628 |
| 12/10/2020 | 0.112 | -2.1893 |
| 12/11/2020 | 0.103 | -2.2730 |
| 12/12/2020 | 0.107 | -2.2349 |
| 12/13/2020 | 0.108 | -2.2256 |
| 12/14/2020 | 0.109 | -2.2164 |
| 12/15/2020 | 0.113 | -2.1804 |
| 12/16/2020 | 0.112 | -2.1893 |
| 12/17/2020 | 0.112 | -2.1893 |
| 12/18/2020 | 0.112 | -2.1893 |
| 12/19/2020 | 0.11 | -2.2073 |
| 12/20/2020 | 0.112 | -2.1893 |
| 12/21/2020 | 0.11 | -2.2073 |
| 12/22/2020 | 0.11 | -2.2073 |
| 12/23/2020 | 0.114 | -2.1716 |
| 12/24/2020 | 0.103 | -2.2730 |
| 12/25/2020 | 0.11 | -2.2073 |
| 12/26/2020 | 0.115 | -2.1628 |
| 12/27/2020 | 0.114 | -2.1716 |
| 12/28/2020 | 0.111 | -2.1982 |
| 12/29/2020 | 0.113 | -2.1804 |
| 12/30/2020 | 0.114 | -2.1716 |
| 12/31/2020 | 0.108 | -2.2256 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 1/1/2021 | 0.112 | -2.1893 |
| 1/2/2021 | 0.109 | -2.2164 |
| 1/3/2021 | 0.11 | -2.2073 |
| 1/4/2021 | 0.111 | -2.1982 |
| 1/5/2021 | 0.11 | -2.2073 |
| 1/6/2021 | 0.111 | -2.1982 |
| 1/7/2021 | 0.113 | -2.1804 |
| 1/8/2021 | 0.114 | -2.1716 |
| 1/9/2021 | 0.115 | -2.1628 |
| 1/10/2021 | 0.113 | -2.1804 |
| 1/11/2021 | 0.111 | -2.1982 |
| 1/12/2021 | 0.114 | -2.1716 |
| 1/13/2021 | 0.106 | -2.2443 |
| 1/14/2021 | 0.115 | -2.1628 |
| 1/15/2021 | 0.114 | -2.1716 |
| 1/16/2021 | 0.108 | -2.2256 |
| 1/17/2021 | 0.111 | -2.1982 |
| 1/18/2021 | 0.11 | -2.2073 |
| 1/19/2021 | 0.113 | -2.1804 |
| 1/20/2021 | 0.113 | -2.1804 |
| 1/21/2021 | 0.114 | -2.1716 |
| 1/22/2021 | 0.112 | -2.1893 |
| 1/23/2021 | 0.114 | -2.1716 |
| 1/24/2021 | 0.114 | -2.1716 |
| 1/25/2021 | 0.113 | -2.1804 |
| 1/26/2021 | 0.11 | -2.2073 |
| 1/27/2021 | 0.11 | -2.2073 |
| 1/28/2021 | 0.114 | -2.1716 |
| 1/29/2021 | 0.117 | -2.1456 |
| 1/30/2021 | 0.116 | -2.1542 |
| 1/31/2021 | 0.113 | -2.1804 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 2/1/2021 | 0.112 | -2.1893 |
| 2/2/2021 | 0.112 | -2.1893 |
| 2/3/2021 | 0.114 | -2.1716 |
| 2/4/2021 | 0.116 | -2.1542 |
| 2/5/2021 | 0.112 | -2.1893 |
| 2/6/2021 | 0.115 | -2.1628 |
| 2/7/2021 | 0.112 | -2.1893 |
| 2/8/2021 | 0.116 | -2.1542 |
| 2/9/2021 | 0.111 | -2.1982 |
| 2/10/2021 | 0.111 | -2.1982 |
| 2/11/2021 | 0.111 | -2.1982 |
| 2/12/2021 | 0.112 | -2.1893 |
| 2/13/2021 | 0.113 | -2.1804 |
| 2/14/2021 | 0.113 | -2.1804 |
| 2/15/2021 | 0.111 | -2.1982 |
| 2/16/2021 | 0.109 | -2.2164 |
| 2/17/2021 | 0.114 | -2.1716 |
| 2/18/2021 | 0.111 | -2.1982 |
| 2/19/2021 | 0.11 | -2.2073 |
| 2/20/2021 | 0.115 | -2.1628 |
| 2/21/2021 | 0.114 | -2.1716 |
| 2/22/2021 | 0.11 | -2.2073 |
| 2/23/2021 | 0.109 | -2.2164 |
| 2/24/2021 | 0.111 | -2.1982 |
| 2/25/2021 | 0.113 | -2.1804 |
| 2/26/2021 | 0.114 | -2.1716 |
| 2/27/2021 | 0.106 | -2.2443 |
| 2/28/2021 | 0.102 | -2.2828 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 3/1/2021 | 0.109 | -2.2164 |
| 3/2/2021 | 0.117 | -2.1456 |
| 3/3/2021 | 0.115 | -2.1628 |
| 3/4/2021 | 0.113 | -2.1804 |
| 3/5/2021 | 0.116 | -2.1542 |
| 3/6/2021 | 0.117 | -2.1456 |
| 3/7/2021 | 0.118 | -2.1371 |
| 3/8/2021 | 0.114 | -2.1716 |
| 3/9/2021 | 0.115 | -2.1628 |
| 3/10/2021 | 0.112 | -2.1893 |
| 3/11/2021 | 0.113 | -2.1804 |
| 3/12/2021 | 0.109 | -2.2164 |
| 3/13/2021 | 0.112 | -2.1893 |
| 3/14/2021 | 0.115 | -2.1628 |
| 3/15/2021 | 0.115 | -2.1628 |
| 3/16/2021 | 0.112 | -2.1893 |
| 3/17/2021 | 0.109 | -2.2164 |
| 3/18/2021 | 0.106 | -2.2443 |
| 3/19/2021 | 0.113 | -2.1804 |
| 3/20/2021 | 0.119 | -2.1286 |
| 3/21/2021 | 0.115 | -2.1628 |
| 3/22/2021 | 0.113 | -2.1804 |
| 3/23/2021 | 0.107 | -2.2349 |
| 3/24/2021 | 0.099 | -2.3126 |
| 3/25/2021 | 0.099 | -2.3126 |
| 3/26/2021 | 0.102 | -2.2828 |
| 3/27/2021 | 0.107 | -2.2349 |
| 3/28/2021 | 0.103 | -2.2730 |
| 3/29/2021 | 0.117 | -2.1456 |
| 3/30/2021 | 0.112 | -2.1893 |
| 3/31/2021 | 0.102 | -2.2828 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 4/1/2021 | 0.113 | -2.1804 |
| 4/2/2021 | 0.117 | -2.1456 |
| 4/3/2021 | 0.119 | -2.1286 |
| 4/4/2021 | 0.116 | -2.1542 |
| 4/5/2021 | 0.115 | -2.1628 |
| 4/6/2021 | 0.113 | -2.1804 |
| 4/7/2021 | 0.108 | -2.2256 |
| 4/8/2021 | 0.108 | -2.2256 |
| 4/9/2021 | 0.096 | -2.3434 |
| 4/10/2021 | 0.093 | -2.3752 |
| 4/11/2021 | 0.092 | -2.3860 |
| 4/12/2021 | 0.097 | -2.3330 |
| 4/13/2021 | 0.107 | -2.2349 |
| 4/14/2021 | 0.096 | -2.3434 |
| 4/15/2021 | 0.099 | -2.3126 |
| 4/16/2021 | 0.103 | -2.2730 |
| 4/17/2021 | 0.102 | -2.2828 |
| 4/18/2021 | 0.107 | -2.2349 |
| 4/19/2021 | 0.094 | -2.3645 |
| 4/20/2021 | 0.1 | -2.3026 |
| 4/21/2021 | 0.101 | -2.2926 |
| 4/22/2021 | 0.112 | -2.1893 |
| 4/23/2021 | 0.115 | -2.1628 |
| 4/24/2021 | 0.111 | -2.1982 |
| 4/25/2021 | 0.107 | -2.2349 |
| 4/26/2021 | 0.116 | -2.1542 |
| 4/27/2021 | 0.108 | -2.2256 |
| 4/28/2021 | 0.103 | -2.2730 |
| 4/29/2021 | 0.098 | -2.3228 |
| 4/30/2021 | 0.11 | -2.2073 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 5/1/2021 | 0.113 | -2.1804 |
| 5/2/2021 | 0.102 | -2.2828 |
| 5/3/2021 | 0.094 | -2.3645 |
| 5/4/2021 | 0.093 | -2.3752 |
| 5/5/2021 | 0.1 | -2.3026 |
| 5/6/2021 | 0.113 | -2.1804 |
| 5/7/2021 | 0.109 | -2.2164 |
| 5/8/2021 | 0.111 | -2.1982 |
| 5/9/2021 | 0.11 | -2.2073 |
| 5/10/2021 | 0.11 | -2.2073 |
| 5/11/2021 | 0.114 | -2.1716 |
| 5/12/2021 | 0.114 | -2.1716 |
| 5/13/2021 | 0.116 | -2.1542 |
| 5/14/2021 | 0.114 | -2.1716 |
| 5/15/2021 | 0.113 | -2.1804 |
| 5/16/2021 | 0.107 | -2.2349 |
| 5/17/2021 | 0.107 | -2.2349 |
| 5/18/2021 | 0.108 | -2.2256 |
| 5/19/2021 | 0.11 | -2.2073 |
| 5/20/2021 | 0.109 | -2.2164 |
| 5/21/2021 | 0.114 | -2.1716 |
| 5/22/2021 | 0.104 | -2.2634 |
| 5/23/2021 | 0.104 | -2.2634 |
| 5/24/2021 | 0.101 | -2.2926 |
| 5/25/2021 | 0.099 | -2.3126 |
| 5/26/2021 | 0.096 | -2.3434 |
| 5/27/2021 | 0.093 | -2.3752 |
| 5/28/2021 | 0.1 | -2.3026 |
| 5/29/2021 | 0.093 | -2.3752 |
| 5/30/2021 | 0.095 | -2.3539 |
| 5/31/2021 | 0.098 | -2.3228 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 6/1/2021 | 0.094 | -2.3645 |
| 6/2/2021 | 0.092 | -2.3860 |
| 6/3/2021 | 0.084 | -2.4769 |
| 6/4/2021 | 0.093 | -2.3752 |
| 6/5/2021 | 0.092 | -2.3860 |
| 6/6/2021 | 0.095 | -2.3539 |
| 6/7/2021 | 0.085 | -2.4651 |
| 6/8/2021 | 0.082 | -2.5010 |
| 6/9/2021 | 0.083 | -2.4889 |
| 6/10/2021 | 0.084 | -2.4769 |
| 6/11/2021 | 0.086 | -2.4534 |
| 6/12/2021 | 0.092 | -2.3860 |
| 6/13/2021 | 0.09 | -2.4079 |
| 6/14/2021 | 0.092 | -2.3860 |
| 6/15/2021 | 0.095 | -2.3539 |
| 6/16/2021 | 0.103 | -2.2730 |
| 6/17/2021 | 0.104 | -2.2634 |
| 6/18/2021 | 0.098 | -2.3228 |
| 6/19/2021 | 0.091 | -2.3969 |
| 6/20/2021 | 0.085 | -2.4651 |
| 6/21/2021 | 0.084 | -2.4769 |
| 6/22/2021 | 0.09 | -2.4079 |
| 6/23/2021 | 0.102 | -2.2828 |
| 6/24/2021 | 0.1 | -2.3026 |
| 6/25/2021 | 0.094 | -2.3645 |
| 6/26/2021 | 0.086 | -2.4534 |
| 6/27/2021 | 0.087 | -2.4418 |
| 6/28/2021 | 0.086 | -2.4534 |
| 6/29/2021 | 0.088 | -2.4304 |
| 6/30/2021 | 0.089 | -2.4191 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 7/1/2021 | 0.085 | -2.4651 |
| 7/2/2021 | 0.091 | -2.3969 |
| 7/3/2021 | 0.095 | -2.3539 |
| 7/4/2021 | 0.093 | -2.3752 |
| 7/5/2021 | 0.09 | -2.4079 |
| 7/6/2021 | 0.086 | -2.4534 |
| 7/7/2021 | 0.087 | -2.4418 |
| 7/8/2021 | 0.086 | -2.4534 |
| 7/9/2021 | 0.087 | -2.4418 |
| 7/10/2021 | 0.093 | -2.3752 |
| 7/11/2021 | 0.087 | -2.4418 |
| 7/12/2021 | 0.085 | -2.4651 |
| 7/13/2021 | 0.086 | -2.4534 |
| 7/14/2021 | 0.087 | -2.4418 |
| 7/15/2021 | 0.087 | -2.4418 |
| 7/16/2021 | 0.095 | -2.3539 |
| 7/17/2021 | 0.088 | -2.4304 |
| 7/18/2021 | 0.096 | -2.3434 |
| 7/19/2021 | 0.094 | -2.3645 |
| 7/20/2021 | 0.093 | -2.3752 |
| 7/21/2021 | 0.094 | -2.3645 |
| 7/22/2021 | 0.103 | -2.2730 |
| 7/23/2021 | 0.102 | -2.2828 |
| 7/24/2021 | 0.098 | -2.3228 |
| 7/25/2021 | 0.089 | -2.4191 |
| 7/26/2021 | 0.09 | -2.4079 |
| 7/27/2021 | 0.093 | -2.3752 |
| 7/28/2021 | 0.095 | -2.3539 |
| 7/29/2021 | 0.091 | -2.3969 |
| 7/30/2021 | 0.099 | -2.3126 |
| 7/31/2021 | 0.105 | -2.2538 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 8/1/2021 | 0.093 | -2.3752 |
| 8/2/2021 | 0.1 | -2.3026 |
| 8/3/2021 | 0.098 | -2.3228 |
| 8/4/2021 | 0.098 | -2.3228 |
| 8/5/2021 | 0.098 | -2.3228 |
| 8/6/2021 | 0.096 | -2.3434 |
| 8/7/2021 | 0.093 | -2.3752 |
| 8/8/2021 | 0.094 | -2.3645 |
| 8/9/2021 | 0.086 | -2.4534 |
| 8/10/2021 | 0.083 | -2.4889 |
| 8/11/2021 | 0.083 | -2.4889 |
| 8/12/2021 | 0.083 | -2.4889 |
| 8/13/2021 | 0.085 | -2.4651 |
| 8/14/2021 | 0.084 | -2.4769 |
| 8/15/2021 | 0.089 | -2.4191 |
| 8/16/2021 | 0.083 | -2.4889 |
| 8/17/2021 | 0.084 | -2.4769 |
| 8/18/2021 | 0.08 | -2.5257 |
| 8/19/2021 | 0.084 | -2.4769 |
| 8/20/2021 | 0.084 | -2.4769 |
| 8/21/2021 | 0.084 | -2.4769 |
| 8/22/2021 | 0.085 | -2.4651 |
| 8/23/2021 | 0.084 | -2.4769 |
| 8/24/2021 | 0.085 | -2.4651 |
| 8/25/2021 | 0.086 | -2.4534 |
| 8/26/2021 | 0.09 | -2.4079 |
| 8/27/2021 | 0.089 | -2.4191 |
| 8/28/2021 | 0.088 | -2.4304 |
| 8/29/2021 | 0.088 | -2.4304 |
| 8/30/2021 | 0.088 | -2.4304 |
| 8/31/2021 | 0.089 | -2.4191 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 9/1/2021 | 0.088 | -2.4304 |
| 9/2/2021 | 0.106 | -2.2443 |
| 9/3/2021 | 0.106 | -2.2443 |
| 9/4/2021 | 0.102 | -2.2828 |
| 9/5/2021 | 0.096 | -2.3434 |
| 9/6/2021 | 0.101 | -2.2926 |
| 9/7/2021 | 0.103 | -2.2730 |
| 9/8/2021 | 0.094 | -2.3645 |
| 9/9/2021 | 0.097 | -2.3330 |
| 9/10/2021 | 0.102 | -2.2828 |
| 9/11/2021 | 0.095 | -2.3539 |
| 9/12/2021 | 0.093 | -2.3752 |
| 9/13/2021 | 0.091 | -2.3969 |
| 9/14/2021 | 0.074 | -2.6037 |
| 9/15/2021 | 0.026 | -3.6497 |
| 9/16/2021 | 0.027 | -3.6119 |
| 9/17/2021 | 0.023 | -3.7723 |
| 9/18/2021 | 0.028 | -3.5756 |
| 9/19/2021 | 0.047 | -3.0576 |
| 9/20/2021 | 0.098 | -2.3228 |
| 9/21/2021 | 0.094 | -2.3645 |
| 9/22/2021 | 0.088 | -2.4304 |
| 9/23/2021 | 0.09 | -2.4079 |
| 9/24/2021 | 0.032 | -3.4420 |
| 9/25/2021 | 0.058 | -2.8473 |
| 9/26/2021 | 0.101 | -2.2926 |
| 9/27/2021 | 0.099 | -2.3126 |
| 9/28/2021 | 0.095 | -2.3539 |
| 9/29/2021 | 0.102 | -2.2828 |
| 9/30/2021 | 0.093 | -2.3752 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 10/1/2021 | 0.099 | -2.3126 |
| 10/2/2021 | 0.097 | -2.3330 |
| 10/3/2021 | 0.092 | -2.3860 |
| 10/4/2021 | 0.092 | -2.3860 |
| 10/5/2021 | 0.09 | -2.4079 |
| 10/6/2021 | 0.091 | -2.3969 |
| 10/7/2021 | 0.095 | -2.3539 |
| 10/8/2021 | 0.094 | -2.3645 |
| 10/9/2021 | 0.095 | -2.3539 |
| 10/10/2021 | 0.092 | -2.3860 |
| 10/11/2021 | 0.094 | -2.3645 |
| 10/12/2021 | 0.093 | -2.3752 |
| 10/13/2021 | 0.092 | -2.3860 |
| 10/14/2021 | 0.094 | -2.3645 |
| 10/15/2021 | 0.092 | -2.3860 |
| 10/16/2021 | 0.095 | -2.3539 |
| 10/17/2021 | 0.105 | -2.2538 |
| 10/18/2021 | 0.105 | -2.2538 |
| 10/19/2021 | 0.106 | -2.2443 |
| 10/20/2021 | 0.103 | -2.2730 |
| 10/21/2021 | 0.101 | -2.2926 |
| 10/22/2021 | 0.102 | -2.2828 |
| 10/23/2021 | 0.099 | -2.3126 |
| 10/24/2021 | 0.101 | -2.2926 |
| 10/25/2021 | 0.098 | -2.3228 |
| 10/26/2021 | 0.101 | -2.2926 |
| 10/27/2021 | 0.102 | -2.2828 |
| 10/28/2021 | 0.09 | -2.4079 |
| 10/29/2021 | 0.093 | -2.3752 |
| 10/30/2021 | 0.099 | -2.3126 |
| 10/31/2021 | 0.097 | -2.3330 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 11/1/2021 | 0.099 | -2.3126 |
| 11/2/2021 | 0.101 | -2.2926 |
| 11/3/2021 | 0.103 | -2.2730 |
| 11/4/2021 | 0.103 | -2.2730 |
| 11/5/2021 | 0.109 | -2.2164 |
| 11/6/2021 | 0.105 | -2.2538 |
| 11/7/2021 | 0.106 | -2.2443 |
| 11/8/2021 | 0.11 | -2.2073 |
| 11/9/2021 | 0.1 | -2.3026 |
| 11/10/2021 | 0.102 | -2.2828 |
| 11/11/2021 | 0.098 | -2.3228 |
| 11/12/2021 | 0.099 | -2.3126 |
| 11/13/2021 | 0.105 | -2.2538 |
| 11/14/2021 | 0.106 | -2.2443 |
| 11/15/2021 | 0.112 | -2.1893 |
| 11/16/2021 | 0.108 | -2.2256 |
| 11/17/2021 | 0.108 | -2.2256 |
| 11/18/2021 | 0.122 | -2.1037 |
| 11/19/2021 | 0.112 | -2.1893 |
| 11/20/2021 | 0.112 | -2.1893 |
| 11/21/2021 | 0.107 | -2.2349 |
| 11/22/2021 | 0.107 | -2.2349 |
| 11/23/2021 | 0.114 | -2.1716 |
| 11/24/2021 | 0.107 | -2.2349 |
| 11/25/2021 | 0.106 | -2.2443 |
| 11/26/2021 | 0.109 | -2.2164 |
| 11/27/2021 | 0.111 | -2.1982 |
| 11/28/2021 | 0.11 | -2.2073 |
| 11/29/2021 | 0.114 | -2.1716 |
| 11/30/2021 | 0.113 | -2.1804 |

| West Stack $NO_X$ Emissions | | |
|---|---|---|
| Date | $NO_X$ (lb/MMBtu) | Ln of Raw Data |
| 12/1/2021 | 0.110 | -2.2073 |
| 12/2/2021 | 0.106 | -2.2443 |
| 12/3/2021 | 0.110 | -2.2073 |
| 12/4/2021 | 0.109 | -2.2164 |
| 12/5/2021 | 0.111 | -2.1982 |
| 12/6/2021 | 0.107 | -2.2349 |
| 12/7/2021 | 0.116 | -2.1542 |
| 12/8/2021 | 0.114 | -2.1716 |
| 12/9/2021 | 0.112 | -2.1893 |
| 12/10/2021 | 0.107 | -2.2349 |
| 12/11/2021 | 0.101 | -2.2926 |
| 12/12/2021 | 0.112 | -2.1893 |
| 12/13/2021 | 0.110 | -2.2073 |
| 12/14/2021 | 0.107 | -2.2349 |
| 12/15/2021 | 0.106 | -2.2443 |
| 12/16/2021 | 0.105 | -2.2538 |
| 12/17/2021 | 0.108 | -2.2256 |
| 12/18/2021 | 0.109 | -2.2164 |
| 12/19/2021 | 0.111 | -2.1982 |
| 12/20/2021 | 0.114 | -2.1716 |
| 12/21/2021 | 0.111 | -2.1982 |
| 12/22/2021 | 0.111 | -2.1982 |
| 12/23/2021 | 0.115 | -2.1628 |
| 12/24/2021 | 0.112 | -2.1893 |
| 12/25/2021 | 0.104 | -2.2634 |
| 12/26/2021 | 0.106 | -2.2443 |
| 12/27/2021 | 0.109 | -2.2164 |
| 12/28/2021 | 0.107 | -2.2349 |
| 12/29/2021 | 0.102 | -2.2828 |
| 12/30/2021 | 0.099 | -2.3126 |
| 12/31/2021 | 0.100 | -2.3026 |

| Testing Normality | Raw Data | Logtransformed Data | | |
|---|---|---|---|---|
| Sample Size | 1091.00 | 1091.00 | | |
| Kurtosis | 4.94 | 10.59 | | |
| SE Kurtosis | 0.15 | 0.15 | | |
| Result Kurtosis | non normal | non normal | | |
| Skewness | -2.12 | -3.21 | | |
| SE Skewness | 0.07 | 0.07 | Result Raw Data | Result Log Data |
| Result Skewness | non normal | non normal | non normal | non normal |

| | |
|---|---|
| Average of Raw Data | 9.91E-02 |
| Variance of Raw Data | 4.41E-04 |

2. Calculate sample size, n= 1091

3. Calculate $\hat{\mu} = \frac{\sum_{i=1}^{n} x_i}{n}$ -2.35E+00

4. Calculate $\hat{\sigma}^2 = \frac{\sum_{i=1}^{n} (x_i - \overline{x})^2}{n-1}$ 0.108421516

5. m= number future runs = 1

6. Calculate $\beta_{2z} = \frac{e^{4\hat{\sigma}^2} + 2e^{3\hat{\sigma}^2} + 3e^{2\hat{\sigma}^2} - 3}{m\left(e^{\hat{\sigma}^2} - 1\right)^2} + 3\left(1 - \frac{1}{m}\right)$

a- Numerator first term $e^{4\hat{\sigma}^2} + 2e^{3\hat{\sigma}^2} + 3e^{2\hat{\sigma}^2} - 3$ 5.038175402

b- denominator first term $m\left(e^{\hat{\sigma}^2} - 1\right)^2$ 0.013114242

$\beta_{2z}$ 384.1758629

7. Calculate $\sqrt{\beta_{1z}} = \frac{\sqrt{e^{\hat{\sigma}^2} - 1}\left(e^{\hat{\sigma}^2} + 2\right)}{\sqrt{m}}$ 1.05396592

8. Go to tab distribution for 99 percentile "*z-stat*"

9. substitue the values of $\beta_{2z}$ $\sqrt{\beta_{1z}}$ in cell D7 and F7 respectively

10. In column AE indentify the value that is the smallest value that is larger than 0.99, note what row number this is.

11. In column B, go down the the row number from Step 10. above, and copy the z value. 3.484 z value from "*z-stat* "

12. calculate the UPL using the formula

$$UPL = e^{\hat{\mu}+\frac{\hat{\sigma}^2}{2}} + \frac{z_{.99}}{m}\sqrt{me^{2\hat{\mu}+\hat{\sigma}^2}(e^{\hat{\sigma}^2}-1)+m^2e^{2\hat{\mu}+\hat{\sigma}^2}\left(\frac{\hat{\sigma}^2}{n}+\frac{\hat{\sigma}^4}{2(n-1)}\right)}$$

a- Calculate $e^{\hat{\mu}+\frac{\hat{\sigma}^2}{2}}$ 0.100612465

b- Calculate $e^{2\hat{\mu}+\hat{\sigma}^2}$ 0.010122868

c- Calculate $(e^{\hat{\sigma}^2}-1)$ 0.114517433

d-calculate $\left(\frac{\hat{\sigma}^2}{n}+\frac{\hat{\sigma}^4}{2(n-1)}\right)$ 0.00010477

e- Calculate $\sqrt{me^{2\hat{\mu}+\hat{\sigma}^2}(e^{\hat{\sigma}^2}-1)+m^2e^{2\hat{\mu}+\hat{\sigma}^2}\left(\frac{\hat{\sigma}^2}{n}+\frac{\hat{\sigma}^4}{2(n-1)}\right)}$ 0.034063

f- Calculate UPL $\boxed{0.219}$

| Δz | z | $\beta_{2z}$ | $\sqrt{\beta_{1z}}$ | $\left(1-\frac{\sqrt{\beta_{1z}}}{6}\left(3z-z^3\right)+\frac{\left(\beta_{2z}-3\right)\left(3-6z^2+z^4\right)}{24}\right)$ | Normal distribution $\phi(z)$ | distribution of Z $f_G(z)=\left(1-\frac{\sqrt{\beta_{1z}}}{6}\left(3z-z^3\right)+\frac{\left(\beta_{2z}-3\right)\left(3-6z^2+z^4\right)}{24}\right)\phi(z)$ | Absolute values | $\frac{\Delta x}{2}\left(f(a)+2\sum_{i=1}^{M}f(x_i)+f(b)\right)$ | Cumulative | normalization |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.101 | | 384.1759 | 1.053966 | | | | | | | |
| | -5 =f(a) | | | 7573.43 | 1.48672E-06 | 0.011259566 | 0.011259566 | 0.000568608 | 0.000568608 | 1.27647E-05 |
| 1 | -4.899 | | | 6891.875 | 2.45094E-06 | 0.016891569 | 0.016891569 | 0.001706049 | 0.002274657 | 5.10639E-05 |
| 2 | -4.798 | | | 6254.987 | 3.9995E-06 | 0.025016836 | 0.025016836 | 0.0025267 | 0.004801357 | 0.000107786 |
| 3 | -4.697 | | | 5660.863 | 6.46025E-06 | 0.036570572 | 0.036570572 | 0.003693628 | 0.008494985 | 0.000190705 |
| 4 | -4.596 | | | 5107.64 | 1.03291E-05 | 0.052757267 | 0.052757267 | 0.005328484 | 0.013823469 | 0.000310324 |
| 5 | -4.495 | | | 4593.495 | 1.63472E-05 | 0.075090993 | 0.075090993 | 0.00758419 | 0.021407659 | 0.000480582 |
| 6 | -4.394 | | | 4116.642 | 2.56093E-05 | 0.105424163 | 0.105424163 | 0.01064784 | 0.032055499 | 0.000719616 |
| 7 | -4.293 | | | 3675.339 | 3.97118E-05 | 0.145954186 | 0.145954186 | 0.014741373 | 0.046796872 | 0.001050546 |
| 8 | -4.192 | | | 3267.879 | 6.09553E-05 | 0.199194386 | 0.199194386 | 0.020118633 | 0.066915505 | 0.001502191 |
| 9 | -4.091 | | | 2892.598 | 9.26132E-05 | 0.267892746 | 0.267892746 | 0.027057167 | 0.093972673 | 0.002109599 |
| 10 | -3.99 | | | 2547.871 | 0.000139285 | 0.354880196 | 0.354880196 | 0.0358429 | 0.129815572 | 0.002914239 |
| 11 | -3.889 | | | 2232.112 | 0.000207351 | 0.462830004 | 0.462830004 | 0.04674583 | 0.176561403 | 0.003963639 |
| 12 | -3.788 | | | 1943.775 | 0.000305546 | 0.593912444 | 0.593912444 | 0.059985157 | 0.23654656 | 0.005310251 |
| 13 | -3.687 | | | 1681.353 | 0.000445674 | 0.749335136 | 0.749335136 | 0.075682849 | 0.312229408 | 0.00700926 |
| 14 | -3.586 | | | 1443.38 | 0.000643469 | 0.928770299 | 0.928770299 | 0.0938058 | 0.406035209 | 0.009115113 |
| 15 | -3.485 | | | 1228.428 | 0.000919619 | 1.129686014 | 1.129686014 | 0.114098287 | 0.520133496 | 0.011676514 |
| 16 | -3.384 | | | 1035.111 | 0.001300942 | 1.346619439 | 1.346619439 | 0.136008563 | 0.656142059 | 0.01472978 |
| 17 | -3.283 | | | 862.0801 | 0.001821704 | 1.570454681 | 1.570454681 | 0.158615923 | 0.814757982 | 0.01829056 |
| 18 | -3.182 | | | 708.0278 | 0.002525035 | 1.787794595 | 1.787794595 | 0.180567254 | 0.995325236 | 0.022344127 |
| 19 | -3.081 | | | 571.6855 | 0.003464389 | 1.980540796 | 1.980540796 | 0.20003462 | 1.195359857 | 0.026834718 |
| 20 | -2.98 | | | 451.8245 | 0.004704958 | 2.125815006 | 2.125815006 | 0.214707316 | 1.410067172 | 0.031654698 |
| 21 | -2.879 | | | 347.2557 | 0.006324913 | 2.196362236 | 2.196362236 | 0.221832586 | 1.631899758 | 0.036634634 |
| 22 | -2.778 | | | 256.8298 | 0.008416337 | 2.161566436 | 2.161566436 | 0.21831821 | 1.850217968 | 0.041535675 |
| 23 | -2.677 | | | 179.437 | 0.011085658 | 1.989177375 | 1.989177375 | 0.200906915 | 2.051124883 | 0.046045848 |
| 24 | -2.576 | | | 114.0072 | 0.014453386 | 1.647790329 | 1.647790329 | 0.166426823 | 2.217551706 | 0.049781976 |
| 25 | -2.475 | | | 59.51004 | 0.018652949 | 1.11003767 | 1.11003767 | 0.112113805 | 2.329665511 | 0.052298827 |
| 26 | -2.374 | | | 14.95473 | 0.023828414 | 0.356347523 | 0.356347523 | 0.0359911 | 2.365656611 | 0.053106793 |
| 27 | -2.273 | | | -20.6098 | 0.030130931 | -0.620991902 | 0.620991902 | 0.062720182 | 2.428376793 | 0.054514803 |
| 28 | -2.172 | | | -48.0949 | 0.03771375 | -1.813839526 | 1.813839526 | 0.183197792 | 2.611574585 | 0.058627423 |
| 29 | -2.071 | | | -68.3724 | 0.046725789 | -3.194754887 | 3.194754887 | 0.322670244 | 2.934244829 | 0.065871071 |
| 30 | -1.97 | | | -82.2744 | 0.057303789 | -4.714632449 | 4.714632449 | 0.476177877 | 3.410422706 | 0.076560822 |
| 31 | -1.869 | | | -90.5932 | 0.069563239 | -6.3019543 | 6.3019543 | 0.636497384 | 4.04692009 | 0.090849597 |
| 32 | -1.768 | | | -94.0816 | 0.083588399 | -7.864130245 | 7.864130245 | 0.794277155 | 4.841197245 | 0.108680381 |
| 33 | -1.667 | | | -93.4527 | 0.099421884 | -9.291246469 | 9.291246469 | 0.938415893 | 5.779613138 | 0.129746946 |
| 34 | -1.566 | | | -89.38 | 0.117054396 | -10.46232016 | 10.46232016 | 1.056694336 | 6.836307475 | 0.153468752 |
| 35 | -1.465 | | | -82.4971 | 0.136415346 | -11.2538731 | 11.2538731 | 1.136641183 | 7.972948658 | 0.178985291 |
| 36 | -1.364 | | | -73.3982 | 0.157365126 | -11.55032056 | 11.55032056 | 1.166582377 | 9.139531034 | 0.205173981 |
| 37 | -1.263 | | | -62.6377 | 0.179689839 | -11.25536185 | 11.25536185 | 1.136791547 | 10.27632258 | 0.230693896 |
| 38 | -1.162 | | | -50.7304 | 0.203099244 | -10.30330005 | 10.30330005 | 1.040633305 | 11.31695589 | 0.254055147 |
| 39 | -1.061 | | | -38.1513 | 0.227228529 | -8.66905697 | 8.66905697 | 0.875574754 | 12.19253064 | 0.273710986 |
| 40 | -0.96 | | | -25.3358 | 0.251644341 | -6.375622167 | 6.375622167 | 0.643937839 | 12.83646848 | 0.288166793 |
| 41 | -0.859 | | | -12.6799 | 0.275855243 | -3.497806242 | 3.497806242 | 0.35327843 | 13.18974691 | 0.296097565 |
| 42 | -0.758 | | | -0.53942 | 0.299326439 | -0.161461403 | 0.161461403 | 0.016307602 | 13.20605451 | 0.296463656 |
| 43 | -0.657 | | | 10.76906 | 0.321498297 | 3.462233897 | 3.462233897 | 0.349685624 | 13.55574013 | 0.304313773 |
| 44 | -0.556 | | | 20.96879 | 0.341807853 | 7.167298167 | 7.167298167 | 0.723897115 | 14.27963725 | 0.320564591 |
| 45 | -0.455 | | | 29.82269 | 0.359712192 | 10.72758393 | 10.72758393 | 1.083485977 | 15.36312323 | 0.344887845 |
| 46 | -0.354 | | | 37.1333 | 0.37471238 | 13.91430769 | 13.91430769 | 1.405345077 | 16.7684683 | 0.376436536 |
| 47 | -0.253 | | | 42.74287 | 0.386376486 | 16.51483824 | 16.51483824 | 1.667998663 | 18.43646697 | 0.413881556 |
| 48 | -0.152 | | | 46.53327 | 0.394360216 | 18.3508718 | 18.3508718 | 1.853438052 | 20.28990502 | 0.455489519 |
| 49 | -0.051 | | | 48.42608 | 0.398423793 | 19.29410389 | 19.29410389 | 1.948704493 | 22.23860951 | 0.499236125 |
| 50 | 0.05 | | | 48.38252 | 0.398443914 | 19.27772065 | 19.27772065 | 1.947049786 | 24.1856593 | 0.542945583 |
| 51 | 0.151 | | | 46.40347 | 0.394419966 | 18.30245606 | 18.30245606 | 1.848548062 | 26.03420736 | 0.58444377 |
| 52 | 0.252 | | | 42.5295 | 0.386474058 | 16.43654685 | 16.43654685 | 1.660091232 | 27.69429859 | 0.621711276 |
| 53 | 0.353 | | | 36.84081 | 0.374844865 | 13.80958851 | 13.80958851 | 1.394768439 | 29.08906703 | 0.653022532 |
| 54 | 0.454 | | | 29.4573 | 0.359875719 | 10.60096738 | 10.60096738 | 1.070697706 | 30.15976474 | 0.677058701 |
| 55 | 0.555 | | | 20.53852 | 0.34199778 | 7.024127964 | 7.024127964 | 0.709436924 | 30.86920166 | 0.692984901 |
| 56 | 0.656 | | | 10.28368 | 0.32170943 | 3.308357054 | 3.308357054 | 0.334144062 | 31.20334572 | 0.700486124 |
| 57 | 0.757 | | | -1.06833 | 0.299553264 | -0.320022626 | 0.320022626 | 0.032322285 | 31.23566801 | 0.70121173 |
| 58 | 0.858 | | | -13.239 | 0.276092166 | -3.655177311 | 3.655177311 | 0.369172908 | 31.60484092 | 0.709499319 |
| 59 | 0.959 | | | -25.91 | 0.25188591 | -6.526372391 | 6.526372391 | 0.659163612 | 32.26400453 | 0.724296929 |
| 60 | 1.06 | | | -38.7236 | 0.227469632 | -8.808450162 | 8.808450162 | 0.889653466 | 33.15365799 | 0.744268823 |
| 61 | 1.161 | | | -51.2822 | 0.203335281 | -10.42748566 | 10.42748566 | 1.053176052 | 34.20683405 | 0.767911647 |
| 62 | 1.262 | | | -63.1486 | 0.17991684 | -11.36149795 | 11.36149795 | 1.147511293 | 35.35434534 | 0.79367221 |
| 63 | 1.363 | | | -73.8459 | 0.157579839 | -11.63662585 | 11.63662585 | 1.175299211 | 36.52964455 | 0.820056585 |
| 64 | 1.464 | | | -82.8576 | 0.136615273 | -11.31961075 | 11.31961075 | 1.143280686 | 37.67292523 | 0.845722174 |
| 65 | 1.565 | | | -89.6274 | 0.117237788 | -10.5077211 | 10.5077211 | 1.061279831 | 38.73420507 | 0.869546921 |
| 66 | 1.666 | | | -93.5596 | 0.099587708 | -9.317383713 | 9.317383713 | 0.941055755 | 39.67526082 | 0.890672748 |
| 67 | 1.767 | | | -94.0185 | 0.083736272 | -7.872758245 | 7.872758245 | 0.795148583 | 40.4704094 | 0.908523095 |
| 68 | 1.868 | | | -90.329 | 0.069693339 | -6.295328349 | 6.295328349 | 0.635828163 | 41.10623757 | 0.922796847 |
| 69 | 1.969 | | | -81.7762 | 0.05741676 | -4.695322906 | 4.695322906 | 0.474227613 | 41.58046518 | 0.933442816 |
| 70 | 2.07 | | | -67.6055 | 0.046822635 | -3.16546944 | 3.16546944 | 0.319712413 | 41.90017759 | 0.940620063 |
| 71 | 2.171 | | | -47.0229 | 0.037795734 | -1.777264272 | 1.777264272 | 0.179503692 | 42.07968129 | 0.944649754 |
| 72 | 2.272 | | | -19.1943 | 0.030199481 | -0.579659059 | 0.579659059 | 0.058545565 | 42.13822685 | 0.945964048 |
| 73 | 2.373 | | | 16.75361 | 0.023885038 | 0.400160695 | 0.400160695 | 0.04041623 | 42.17864308 | 0.946871354 |
| 74 | 2.474 | | | 61.73417 | 0.018699163 | 1.154377228 | 1.154377228 | 0.1165921 | 42.29523518 | 0.949488739 |
| 75 | 2.575 | | | 116.7002 | 0.014490659 | 1.691062521 | 1.691062521 | 0.170797315 | 42.4660325 | 0.95332298 |
| 76 | 2.676 | | | 182.6442 | 0.011115369 | 2.030157378 | 2.030157378 | 0.205045895 | 42.67107839 | 0.95792607 |
| 77 | 2.777 | | | 260.5983 | 0.008439746 | 2.19938383 | 2.19938383 | 0.222137767 | 42.89321616 | 0.962912856 |
| 78 | 2.878 | | | 351.6345 | 0.006343145 | 2.230468844 | 2.230468844 | 0.225277353 | 43.11849351 | 0.967970124 |
| 79 | 2.979 | | | 456.8642 | 0.004718997 | 2.155940932 | 2.155940932 | 0.217750034 | 43.33624354 | 0.972858409 |
| 80 | 3.08 | | | 577.4387 | 0.003475077 | 2.00664414 | 2.00664414 | 0.202671058 | 43.5389146 | 0.977408186 |

| Δz | z | $\beta_{2z}$ | $\sqrt{\beta_{1z}}$ | $\left(1-\frac{\sqrt{\beta_{1z}}}{6}\left(3z-z^3\right)+\frac{\left(\beta_{2z}-3\right)\left(3-6z^2+z^4\right)}{24}\right)$ | Normal distribution $\phi(z)$ | distribution of Z $f_G(z)=\left(1-\frac{\sqrt{\beta_{1z}}}{6}\left(3z-z^3\right)+\frac{\left(\beta_{2z}-3\right)\left(3-6z^2+z^4\right)}{24}\right)\phi(z)$ | Absolute values | $\frac{\Delta x}{2}\left(f(a)+2\sum_{i=1}^{M}f(x_i)+f(b)\right)$ | Cumulative | normalization |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.101 | | 384.1759 | 1.053966 | | | | | | | |
| | -5 =f(a) | | | 7573.43 | 1.48672E-06 | 0.011259566 | 0.011259566 | 0.000568608 | 0.000568608 | 1.27647E-05 |
| 81 | 3.181 | | | 714.5487 | 0.002533081 | 1.810009587 | 1.810009587 | 0.182810968 | 43.72172557 | 0.981512123 |
| 82 | 3.282 | | | 869.4248 | 0.001827693 | 1.589042028 | 1.589042028 | 0.160493245 | 43.88221882 | 0.985115047 |
| 83 | 3.383 | | | 1043.337 | 0.001305351 | 1.36192163 | 1.36192163 | 0.137554085 | 44.0197729 | 0.988203009 |
| 84 | 3.484 | | | 1237.596 | 0.000922829 | 1.142089271 | 1.142089271 | 0.115351016 | 44.13512392 | 0.990792532 |
| 85 | 3.585 | | | 1453.55 | 0.00064578 | 0.938673982 | 0.938673982 | 0.094806072 | 44.22992999 | 0.99292084 |
| 86 | 3.686 | | | 1692.589 | 0.00044732 | 0.757128627 | 0.757128627 | 0.076469991 | 44.30639998 | 0.99463752 |
| 87 | 3.787 | | | 1956.141 | 0.000306705 | 0.59995899 | 0.59995899 | 0.060595858 | 44.36699584 | 0.995997841 |
| 88 | 3.888 | | | 2245.676 | 0.000208159 | 0.467456634 | 0.467456634 | 0.04721312 | 44.41420896 | 0.997057732 |
| 89 | 3.989 | | | 2562.701 | 0.000139842 | 0.358372618 | 0.358372618 | 0.036195634 | 44.45040459 | 0.99787029 |
| 90 | 4.09 | | | 2908.764 | 9.29928E-05 | 0.270494104 | 0.270494104 | 0.027319905 | 44.4777245 | 0.998483596 |
| 91 | 4.191 | | | 3285.453 | 6.12113E-05 | 0.201106785 | 0.201106785 | 0.020311785 | 44.49803628 | 0.998939577 |
| 92 | 4.292 | | | 3694.395 | 3.98826E-05 | 0.147342042 | 0.147342042 | 0.014881546 | 44.51291783 | 0.999273654 |
| 93 | 4.393 | | | 4137.256 | 2.5722E-05 | 0.106418586 | 0.106418586 | 0.010748277 | 44.52366611 | 0.999514943 |
| 94 | 4.494 | | | 4615.743 | 1.64209E-05 | 0.075794591 | 0.075794591 | 0.007655254 | 44.53132136 | 0.999686796 |
| 95 | 4.595 | | | 5131.603 | 1.03767E-05 | 0.053248925 | 0.053248925 | 0.005378141 | 44.5366995 | 0.999807531 |
| 96 | 4.696 | | | 5686.621 | 6.49066E-06 | 0.036909916 | 0.036909916 | 0.003727901 | 44.5404274 | 0.999891218 |
| 97 | 4.797 | | | 6282.622 | 4.01874E-06 | 0.025248203 | 0.025248203 | 0.002550069 | 44.54297747 | 0.999948465 |
| 98 | 4.898 | | | 6921.473 | 2.46298E-06 | 0.017047415 | 0.017047415 | 0.001721789 | 44.54469926 | 0.999987118 |
| 99 | 4.999 | | | 7605.077 | 1.49417E-06 | 0.011363285 | 0.011363285 | 0.000573846 | 44.54527311 | 1 |

# APPENDIX D. SCR AND SNCR COST ANALYSIS

As discussed in Section 2, SCR and SNCR are not technically feasible for CPP's boilers due to low exhaust temperatures. However, in anticipation of questions from DOEE, CPP provided a cost effectiveness evaluation in the original alternative RACT plan to demonstrate that SCR and SNCR are both technically infeasible and not cost effective for Boilers 3 through 7. DOEE's June 23, 2023 proposal accepted that SCR and SNCR are not technically feasible. For completeness, the cost effectiveness calculations are provided again in this appendix but have not been updated.

Due to space restrictions and routing of the existing exhaust stacks, the only way to install SNCR or SCR technology on Boilers 3 through 7 would be to install an SCR/SNCR on Boiler 3, a single SCR/SNCR controlling emissions from Boilers 4 and 5, and a separate single SCR/SNCR controlling emissions from Boilers 6 and 7.

SCR cost analyses in this appendix were calculated based on EPA's *SCR Cost Calculation Spreadsheet*.[14] SNCR cost analyses were calculated based on EPA's *Air Pollution Control Cost Estimation Spreadsheets for Selective Non-Catalytic Reduction (SNCR)*.[15] Note that these spreadsheets do not account for the AOC-specific cost contingency factors utilized in the cost analyses in Appendix A. This, combined with the conservative control efficiencies that likely could not be achieved due to exhaust temperature, causes the cost effectiveness values to be conservative.

This appendix contains detailed cost effectiveness calculations for:

- Installing SCR on Boiler 3
- Installing SNCR on Boiler 3
- Installing SCR on the combined exhaust of Boilers 4 and 5
- Installing SNCR on the combined exhaust of Boilers 4 and 5
- Installing SCR on the combined exhaust of Boilers 6 and 7
- Installing SNCR on the combined exhaust of Boilers 6 and 7

14 https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution.

15 https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution (updated 3/19/2021).

## Boiler 3 (EU-3)
## SCR Design Parameters

**The following design parameters for the SCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 203 | MMBtu/hour | |
| Baseline $NO_X$ Emissions = | Average of 2020-2021 observed emissions | 13.34 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 245,380 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.012 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 1.47 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 11.87 | tons/year | |
| $NO_x$ removal factor (NRF) = | EF/80 = | 1.10 | | |
| Volumetric flue gas flow rate ($q_{flue\ gas}$) = | $Q_{fuel}$ x QB x (460 + T)/(460 + 700)$n_{scr}$ = | 59,679 | acfm | |
| Space velocity ($V_{space}$) = | $q_{flue\ gas}/Vol_{catalyst}$ = | 74.92 | /hour | |
| Residence Time | $1/V_{space}$ | 0.01 | hour | |
| Coal Factor (CoalF) = | 1 for oil and natural gas; 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | 1.00 | | |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at sea level (P) = | 2116 x $[(59-(0.00356xh)+459.7)/518.6]^{5.256}$ x (1/144)* = | 14.7 | psia | |
| Retrofit Factor (RF) | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

### Catalyst Data:

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Future worth factor (FWF) = | (interest rate)(1/((1+ interest rate)$^Y$ -1) , where Y = $H_{catalyts}/(t_{SCR}$ x 24 hours) rounded to the nearest integer | 0.3211 | Fraction |
| Catalyst volume ($Vol_{catalyst}$) = | 2.81 x $Q_B$ x $EF_{adj}$ x Slipadj x $NOx_{adj}$ x $S_{adj}$ x $(T_{adj}/N_{scr})$ | 796.53 | Cubic feet |
| Cross sectional area of the catalyst ($A_{catalyst}$) = | $q_{flue\ gas}$ /(16ft/sec x 60 sec/min) | 62 | $ft^2$ |
| Height of each catalyst layer ($H_{layer}$) = | $(Vol_{catalyst}/(R_{layer}$ x $A_{catalyst}$)) + 1 (rounded to next highest integer) | 5 | feet |

### SCR Reactor Data:

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Cross sectional area of the reactor ($A_{SCR}$) = | 1.15 x $A_{catalyst}$ | 71 | $ft^2$ |
| Reactor length and width dimensions for a square reactor = | $(A_{SCR})^{0.5}$ | 8.5 | feet |
| Reactor height = | $(R_{layer} + R_{empty})$ x (7ft + $h_{layer}$) + 9ft | 58 | feet |

### Reagent Data:

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 $lb/ft^3$

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in}$ x $Q_B$ x EF x SRF x $MW_R)/MW_{NOx}$ = | 7 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}$/Csol = | 25 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density | 3 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24)/Reagent Density = | 1,200 | gallons (storage needed to store a 14 day reagent supply rounded to |

### Capital Recovery Factor:

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | i $(1+ i)^n/(1+ i)^n$ - 1 =<br>Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Other parameters | Equation | Calculated Value | Units |
|---|---|---|---|
| **Electricity Usage:** | | | |
| Electricity Consumption (P) = | A x 1,000 x 0.0056 x (CoalF x HRF)$^{0.43}$ =<br>where A = (0.1 x QB) for industrial boilers. | 104.38 | kW |

# Boiler 3 (EU-3)
# SCR Cost Estimate

## Total Capital Investment (TCI)

**TCI for Oil and Natural Gas Boilers**

For Oil and Natural Gas-Fired Utility Boilers between 25MW and 500 MW:

$$TCI = 86,380 \times (200/B_{MW})^{0.35} \times B_{MW} \times ELEVF \times RF$$

For Oil and Natural Gas-Fired Utility Boilers >500 MW:

$$TCI = 62,680 \times B_{MW} \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers between 275 and 5,500 MMBTU/hour :

$$TCI = 7,850 \times (2,200/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers between 205 and 4,100 MMBTU/hour :

$$TCI = 10,530 \times (1,640/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers >5,500 MMBtu/hour:

$$TCI = 5,700 \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers >4,100 MMBtu/hour:

$$TCI = 7,640 \times Q_B \times ELEVF \times RF$$

| | | |
|---|---|---|
| Total Capital Investment (TCI) = | $5,629,948 | in 2021 dollars |

## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | | |
|---|---|---|
| Direct Annual Costs (DAC) = | $72,675 | in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $408,322 | in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $480,997 | in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

| | | | |
|---|---|---|---|
| Annual Maintenance Cost = | 0.005 x TCI = | $28,150 | in 2021 dollars |
| Annual Reagent Cost = | $m_{sol} \times Cost_{reag} \times t_{op}$ = | $3,415 | in 2021 dollars |
| Annual Electricity Cost = | $P \times Cost_{elect} \times t_{op}$ = | $16,655 | in 2021 dollars |
| Annual Catalyst Replacement Cost = | $n_{scr} \times Vol_{cat} \times (CC_{replace}/R_{layer}) \times FWF$ | $24,455 | in 2021 dollars |
| Direct Annual Cost = | | $72,675 | in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | | |
|---|---|---|---|
| Administrative Charges (AC) = | 0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) = | $2,966 | in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $405,356 | in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $408,322 | in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | | |
|---|---|---|
| Total Annual Cost (TAC) = | $480,997 | per year in 2021 dollars |
| NOx Removed = | 12 | tons/year |
| Cost Effectiveness = | $40,531 | per ton of NOx removed in 2021 dollars |

## Boiler 3 (EU-3)
## SNCR Design Parameters

**The following design parameters for the SNCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 203 | MMBtu/hour | |
| Baseline $NO_X$ Emissions = | Average of 2020-2021 observed emissions | 13.34 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 245,380 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.060 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 7.36 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 5.98 | tons/year | |
| Coal Factor ($Coal_F$) = | 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | | | Not applicable; factor applies only to coal-fired boilers |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*(1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at 25 feet above sea level (P) = | $2116x[(59-(0.00356xh)+459.7)/518.6]^{5.256}$ x (1/144)* = | 14.7 | psia | |
| Retrofit Factor (RF) = | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

**Reagent Data:**

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 lb/gallon

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in}$ x $Q_B$ x NSR x $MW_R)/(MW_{NOx}$ x SR) =<br>(whre SR = 1 for $NH_3$; 2 for Urea) | 8 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}/C_{sol}$ = | 28 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density = | 3.7 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24 hours/day)/Reagent Density = | 1,300 | gallons (storage needed to store a 14 day reagent supply rounded up to the nearest 100 gallons) |

**Capital Recovery Factor:**

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | $i (1+ i)^n/(1+ i)^n - 1$ =<br>Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| **Electricity Usage:**<br>Electricity Consumption (P) = | $(0.47$ x $NOx_{in}$ x NSR x $Q_B)$/NPHR = | 1.2 | kW/hour | |
| **Water Usage:**<br>Water consumption ($q_w$) = | ($m_{sol}$/Density of water) x (($C_{stored}/C_{inj}$) - 1) = | 6 | gallons/hour | |
| **Fuel Data:**<br>Additional Fuel required to evaporate water in injected reagent (ΔFuel) = | Hv x $m_{reagent}$ x ((1/$C_{inj}$)-1) = | 0.07 | MMBtu/hour | |
| **Ash Disposal:**<br>Additional ash produced due to increased fuel consumption (Δash) = | (Δfuel x %Ash x $1x10^6$)/HHV = | 0.0 | lb/hour | Not applicable - Ash disposal cost applies only to coal-fired boilers |

# Boiler 3 (EU-3)
# SNCR Cost Estimate

## Total Capital Investment (TCI)

For Coal-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + APH_{cost} + BOP_{cost})$$

For Fuel Oil and Natural Gas-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + BOP_{cost})$$

| | | |
|---|---|---|
| Capital costs for the SNCR ($SNCR_{cost}$) = | $659,894 | in 2021 dollars |
| Air Pre-Heater Costs ($APH_{cost}$)* = | $0 | in 2021 dollars |
| Balance of Plant Costs ($BOP_{cost}$) = | $1,007,774 | in 2021 dollars |
| Total Capital Investment (TCI) = | $2,167,968 | in 2021 dollars |

#VALUE!

## SNCR Capital Costs ($SNCR_{cost}$)

For Coal-Fired Utility Boilers:

$$SNCR_{cost} = 220{,}000 \times (B_{MW} \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$SNCR_{cost} = 147{,}000 \times (B_{MW} \times HRF)^{0.42} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers:

$$SNCR_{cost} = 220{,}000 \times (0.1 \times Q_B \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$SNCR_{cost} = 147{,}000 \times ((Q_B/NPHR) \times HRF)^{0.42} \times ELEVF \times RF$$

| | | |
|---|---|---|
| SNCR Capital Costs ($SNCR_{cost}$) = | $659,894 | in 2021 dollars |

## Air Pre-Heater Costs ($APH_{cost}$)*

For Coal-Fired Utility Boilers:

$$APH_{cost} = 69{,}000 \times (B_{MW} \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

For Coal-Fired Industrial Boilers:

$$APH_{cost} = 69{,}000 \times (0.1 \times Q_B \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

| | | |
|---|---|---|
| Air Pre-Heater Costs ($APH_{cost}$) = | $0 | in 2021 dollars |

## Balance of Plant Costs ($BOP_{cost}$)

For Coal-Fired Utility Boilers:

$$BOP_{cost} = 320{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$BOP_{cost} = 213{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

For Coal-Fired Industrial Boilers:

$$BOP_{cost} = 320{,}000 \times (0.1 \times Q_B)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$BOP_{cost} = 213{,}000 \times (Q_B/NPHR)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

| | | |
|---|---|---|
| Balance of Plant Costs ($BOP_{cost}$) = | $1,007,774 | in 2021 dollars |

# Boiler 3 (EU-3)
# SNCR Cost Estimate
## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | |
|---|---|
| Direct Annual Costs (DAC) = | $36,750 in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $157,069 in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $193,819 in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Water Cost) + (Annual Fuel Cost) + (Annual Ash Cost)

| | | |
|---|---|---|
| Annual Maintenance Cost = | 0.015 x TCI = | $32,520 in 2021 dollars |
| Annual Reagent Cost = | $q_{sol}$ x $Cost_{reag}$ x $t_{op}$ = | $3,869 in 2021 dollars |
| Annual Electricity Cost = | P x $Cost_{elect}$ x $t_{op}$ = | $102 in 2021 dollars |
| Annual Water Cost = | $q_{water}$ x $Cost_{water}$ x $t_{op}$ = | $32 in 2021 dollars |
| Additional Fuel Cost = | ΔFuel x $Cost_{fuel}$ x $t_{op}$ = | $227 in 2021 dollars |
| Additional Ash Cost = | ΔAsh x $Cost_{ash}$ x $t_{op}$ x (1/2000) = | $0 in 2021 dollars |
| Direct Annual Cost = | | $36,750 in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | |
|---|---|---|
| Administrative Charges (AC) = | 0.03 x Annual Maintenance Cost = | $976 in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $156,094 in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $157,069 in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | |
|---|---|
| Total Annual Cost (TAC) = | $193,819 per year in 2021 dollars |
| NOx Removed = | 6 tons/year |
| Cost Effectiveness = | $32,421 per ton of NOx removed in 2021 dollars |

# Boiler 4,5 (EU-4,5)
## SCR Design Parameters

**The following design parameters for the SCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 120 | MMBtu/hour | |
| Baseline $NO_x$ Emissions = | Average of 2020-2021 observed emissions | 9.04 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 172,660 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.012 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 1.04 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 8.01 | tons/year | |
| $NO_x$ removal factor (NRF) = | EF/80 = | 1.10 | | |
| Volumetric flue gas flow rate ($q_{flue\ gas}$) = | $Q_{fuel}$ x QB x (460 + T)/(460 + 700)$n_{scr}$ = | 52,350 | acfm | |
| Space velocity ($V_{space}$) = | $q_{flue\ gas}/Vol_{catalyst}$ = | 111.18 | /hour | |
| Residence Time | $1/V_{space}$ | 0.01 | hour | |
| Coal Factor (CoalF) = | 1 for oil and natural gas; 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | 1.00 | | |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at sea level (P) = | $2116 \times [(59-(0.00356xh)+459.7)/518.6]^{5.256} \times (1/144)$* = | 14.7 | psia | |
| Retrofit Factor (RF) | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

**Catalyst Data:**

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Future worth factor (FWF) = | (interest rate)(1/((1+ interest rate)$^Y$ -1) , where Y = $H_{catalyts}/(t_{SCR}$ x 24 hours) rounded to the nearest integer | 0.3211 | Fraction |
| Catalyst volume ($Vol_{catalyst}$) = | 2.81 x $Q_B$ x EF $_{adj}$ x Slipadj x $NOx_{adj}$ x $S_{adj}$ x $(T_{adj}/N_{scr})$ | 470.85 | Cubic feet |
| Cross sectional area of the catalyst ($A_{catalyst}$) = | $q_{flue\ gas}$ /(16ft/sec x 60 sec/min) | 55 | $ft^2$ |
| Height of each catalyst layer ($H_{layer}$) = | $(Vol_{catalyst}/(R_{layer}$ x $A_{catalyst}))$ + 1 (rounded to next highest integer) | 4 | feet |

**SCR Reactor Data:**

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Cross sectional area of the reactor ($A_{SCR}$) = | 1.15 x $A_{catalyst}$ | 63 | $ft^2$ |
| Reactor length and width dimensions for a square reactor = | $(A_{SCR})^{0.5}$ | 7.9 | feet |
| Reactor height = | $(R_{layer} + R_{empty})$ x (7ft + $h_{layer}$) + 9ft | 53 | feet |

**Reagent Data:**

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 $lb/ft^3$

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in}$ x $Q_B$ x EF x SRF x $MW_R)/MW_{NOx}$ = | 4 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}/Csol$ = | 15 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density | 2 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24)/Reagent Density = | 700 | gallons (storage needed to store a 14 day reagent supply rounded to |

**Capital Recovery Factor:**

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | $i (1+ i)^n/(1+ i)^n - 1$ = Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Other parameters | Equation | Calculated Value | Units |
|---|---|---|---|
| **Electricity Usage:** | | | |
| Electricity Consumption (P) = | A x 1,000 x 0.0056 x $(CoalF \times HRF)^{0.43}$ = where A = (0.1 x QB) for industrial boilers. | 61.70 | kW |

# Boiler 4,5 (EU-4,5)
# SCR Cost Estimate

## Total Capital Investment (TCI)

**TCI for Oil and Natural Gas Boilers**

For Oil and Natural Gas-Fired Utility Boilers between 25MW and 500 MW:

$$TCI = 86{,}380 \times (200/B_{MW})^{0.35} \times B_{MW} \times ELEVF \times RF$$

For Oil and Natural Gas-Fired Utility Boilers >500 MW:

$$TCI = 62{,}680 \times B_{MW} \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers between 275 and 5,500 MMBTU/hour :

$$TCI = 7{,}850 \times (2{,}200/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers between 205 and 4,100 MMBTU/hour :

$$TCI = 10{,}530 \times (1{,}640/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers >5,500 MMBtu/hour:

$$TCI = 5{,}700 \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers >4,100 MMBtu/hour:

$$TCI = 7{,}640 \times Q_B \times ELEVF \times RF$$

| | | |
|---|---|---|
| Total Capital Investment (TCI) = | $4,000,366 | in 2021 dollars |

## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | | |
|---|---|---|
| Direct Annual Costs (DAC) = | $48,580 | in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $290,894 | in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $339,475 | in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

| | | | |
|---|---|---|---|
| Annual Maintenance Cost = | 0.005 x TCI = | $20,002 | in 2021 dollars |
| Annual Reagent Cost = | $m_{sol} \times Cost_{reag} \times t_{op}$ = | $2,403 | in 2021 dollars |
| Annual Electricity Cost = | $P \times Cost_{elect} \times t_{op}$ = | $11,719 | in 2021 dollars |
| Annual Catalyst Replacement Cost = | $n_{scr} \times Vol_{cat} \times (CC_{replace}/R_{layer}) \times FWF$ | $14,456 | in 2021 dollars |
| Direct Annual Cost = | | $48,580 | in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | | |
|---|---|---|---|
| Administrative Charges (AC) = | 0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) = | $2,868 | in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $288,026 | in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $290,894 | in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | | |
|---|---|---|
| Total Annual Cost (TAC) = | $339,475 | per year in 2021 dollars |
| NOx Removed = | 8 | tons/year |
| Cost Effectiveness = | $42,403 | per ton of NOx removed in 2021 dollars |

# Boiler 4,5 (EU-4,5)
## SNCR Design Parameters

**The following design parameters for the SNCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 120 | MMBtu/hour | |
| Baseline $NO_X$ Emissions = | Average of 2020-2021 observed emissions | 9.04 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 172,660 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.060 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 5.18 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 3.86 | tons/year | |
| Coal Factor ($Coal_F$) = | 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | | | Not applicable; factor applies only to coal-fired boilers |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*(1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at 25 feet above sea level (P) = | $2116x[(59-(0.00356xh)+459.7)/518.6]^{5.256}$ x (1/144)* = | 14.7 | psia | |
| Retrofit Factor (RF) = | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

**Reagent Data:**

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 lb/gallon

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in} \times Q_B \times NSR \times MW_R)/(MW_{NOx} \times SR)$ =<br>(whre SR = 1 for $NH_3$; 2 for Urea) | 5 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}/C_{sol}$ = | 16 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density = | 2.2 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24 hours/day)/Reagent Density = | 800 | gallons (storage needed to store a 14 day reagent supply rounded up to the nearest 100 gallons) |

**Capital Recovery Factor:**

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | $i (1+ i)^n/(1+ i)^n - 1$ =<br>Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| **Electricity Usage:**<br>Electricity Consumption (P) = | $(0.47 \times NOx_{in} \times NSR \times Q_B)/NPHR$ = | 0.7 | kW/hour | |
| **Water Usage:**<br>Water consumption ($q_w$) = | ($m_{sol}$/Density of water) x (($C_{stored}/C_{inj}$) - 1) = | 4 | gallons/hour | |
| **Fuel Data:**<br>Additional Fuel required to evaporate water in injected reagent (ΔFuel) = | Hv x $m_{reagent}$ x $((1/C_{inj})-1)$ = | 0.04 | MMBtu/hour | |
| **Ash Disposal:**<br>Additional ash produced due to increased fuel consumption (Δash) = | $(\Delta fuel \times \%Ash \times 1x10^6)/HHV$ = | 0.0 | lb/hour | Not applicable - Ash disposal cost applies only to coal-fired boilers |

# Boiler 4,5 (EU-4,5)
# SNCR Cost Estimate

## Total Capital Investment (TCI)

For Coal-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + APH_{cost} + BOP_{cost})$$

For Fuel Oil and Natural Gas-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + BOP_{cost})$$

| | | |
|---|---|---|
| Capital costs for the SNCR ($SNCR_{cost}$) = | $529,153 | in 2021 dollars |
| Air Pre-Heater Costs ($APH_{cost}$)* = | $0 | in 2021 dollars |
| Balance of Plant Costs ($BOP_{cost}$) = | $795,466 | in 2021 dollars |
| Total Capital Investment (TCI) = | $1,722,005 | in 2021 dollars |

#VALUE!

### SNCR Capital Costs ($SNCR_{cost}$)

For Coal-Fired Utility Boilers:

$$SNCR_{cost} = 220{,}000 \times (B_{MW} \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$SNCR_{cost} = 147{,}000 \times (B_{MW} \times HRF)^{0.42} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers:

$$SNCR_{cost} = 220{,}000 \times (0.1 \times Q_B \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$SNCR_{cost} = 147{,}000 \times ((Q_B/NPHR) \times HRF)^{0.42} \times ELEVF \times RF$$

| | | |
|---|---|---|
| SNCR Capital Costs ($SNCR_{cost}$) = | $529,153 | in 2021 dollars |

### Air Pre-Heater Costs ($APH_{cost}$)*

For Coal-Fired Utility Boilers:

$$APH_{cost} = 69{,}000 \times (B_{MW} \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

For Coal-Fired Industrial Boilers:

$$APH_{cost} = 69{,}000 \times (0.1 \times Q_B \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

| | | |
|---|---|---|
| Air Pre-Heater Costs ($APH_{cost}$) = | $0 | in 2021 dollars |

#VALUE!

### Balance of Plant Costs ($BOP_{cost}$)

For Coal-Fired Utility Boilers:

$$BOP_{cost} = 320{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$BOP_{cost} = 213{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

For Coal-Fired Industrial Boilers:

$$BOP_{cost} = 320{,}000 \times (0.1 \times Q_B)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$BOP_{cost} = 213{,}000 \times (Q_B/NPHR)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

| | | |
|---|---|---|
| Balance of Plant Costs ($BOP_{cost}$) = | $795,466 | in 2021 dollars |

# Boiler 4,5 (EU-4,5)
# SNCR Cost Estimate
## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | | |
|---|---|---|
| Direct Annual Costs (DAC) = | $28,806 | in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $124,759 | in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $153,566 | in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Water Cost) + (Annual Fuel Cost) + (Annual Ash Cost)

| | | | |
|---|---|---|---|
| Annual Maintenance Cost = | 0.015 x TCI = | $25,830 | in 2021 dollars |
| Annual Reagent Cost = | $q_{sol}$ x $Cost_{reag}$ x $t_{op}$ = | $2,722 | in 2021 dollars |
| Annual Electricity Cost = | P x $Cost_{elect}$ x $t_{op}$ = | $72 | in 2021 dollars |
| Annual Water Cost = | $q_{water}$ x $Cost_{water}$ x $t_{op}$ = | $22 | in 2021 dollars |
| Additional Fuel Cost = | ΔFuel x $Cost_{fuel}$ x $t_{op}$ = | $160 | in 2021 dollars |
| Additional Ash Cost = | ΔAsh x $Cost_{ash}$ x $t_{op}$ x (1/2000) = | $0 | in 2021 dollars |
| Direct Annual Cost = | | $28,806 | in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | | |
|---|---|---|---|
| Administrative Charges (AC) = | 0.03 x Annual Maintenance Cost = | $775 | in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $123,984 | in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $124,759 | in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | | |
|---|---|---|
| Total Annual Cost (TAC) = | $153,566 | per year in 2021 dollars |
| NOx Removed = | 4 | tons/year |
| Cost Effectiveness = | $39,763 | per ton of NOx removed in 2021 dollars |

# Boiler 6,7 (EU-6,7)
## SCR Design Parameters

**The following design parameters for the SCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 120 | MMBtu/hour | |
| Baseline $NO_x$ Emissions = | Average of 2020-2021 observed emissions | 8.20 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 159,266 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.012 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 0.96 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 7.25 | tons/year | |
| $NO_x$ removal factor (NRF) = | EF/80 = | 1.10 | | |
| Volumetric flue gas flow rate ($q_{flue\ gas}$) = | $Q_{fuel}$ x QB x (460 + T)/(460 + 700)$n_{scr}$ = | 52,350 | acfm | |
| Space velocity ($V_{space}$) = | $q_{flue\ gas}/Vol_{catalyst}$ = | 111.18 | /hour | |
| Residence Time | $1/V_{space}$ | 0.01 | hour | |
| Coal Factor (CoalF) = | 1 for oil and natural gas; 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | 1.00 | | |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at sea level (P) = | 2116 x $[(59-(0.00356xh)+459.7)/518.6]^{5.256}$ x (1/144)* = | 14.7 | psia | |
| Retrofit Factor (RF) | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

### Catalyst Data:

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Future worth factor (FWF) = | (interest rate)(1/((1+ interest rate)$^Y$ -1) , where Y = $H_{catalyts}/(t_{SCR}$ x 24 hours) rounded to the nearest integer | 0.3211 | Fraction |
| Catalyst volume ($Vol_{catalyst}$) = | 2.81 x $Q_B$ x EF $_{adj}$ x Slipadj x $NOx_{adj}$ x $S_{adj}$ x $(T_{adj}/N_{scr})$ | 470.85 | Cubic feet |
| Cross sectional area of the catalyst ($A_{catalyst}$) = | $q_{flue\ gas}$ /(16ft/sec x 60 sec/min) | 55 | $ft^2$ |
| Height of each catalyst layer ($H_{layer}$) = | $(Vol_{catalyst}/(R_{layer}$ x $A_{catalyst}))$ + 1 (rounded to next highest integer) | 4 | feet |

### SCR Reactor Data:

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Cross sectional area of the reactor ($A_{SCR}$) = | 1.15 x $A_{catalyst}$ | 63 | $ft^2$ |
| Reactor length and width dimensions for a square reactor = | $(A_{SCR})^{0.5}$ | 7.9 | feet |
| Reactor height = | $(R_{layer} + R_{empty})$ x (7ft + $h_{layer}$) + 9ft | 53 | feet |

### Reagent Data:

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 $lb/ft^3$

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in}$ x $Q_B$ x EF x SRF x $MW_R)/MW_{NOx}$ = | 4 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}$/Csol = | 15 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density | 2 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24)/Reagent Density = | 700 | gallons (storage needed to store a 14 day reagent supply rounded to |

### Capital Recovery Factor:

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | $i (1+ i)^n/(1+ i)^n - 1$ = <br> Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Other parameters | Equation | Calculated Value | Units |
|---|---|---|---|
| **Electricity Usage:** <br> Electricity Consumption (P) = | A x 1,000 x 0.0056 x (CoalF x HRF)$^{0.43}$ = <br> where A = (0.1 x QB) for industrial boilers. | 61.70 | kW |

# Boiler 6,7 (EU-6,7)
# SCR Cost Estimate

## Total Capital Investment (TCI)

**TCI for Oil and Natural Gas Boilers**

For Oil and Natural Gas-Fired Utility Boilers between 25MW and 500 MW:

$$TCI = 86{,}380 \times (200/B_{MW})^{0.35} \times B_{MW} \times ELEVF \times RF$$

For Oil and Natural Gas-Fired Utility Boilers >500 MW:

$$TCI = 62{,}680 \times B_{MW} \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers between 275 and 5,500 MMBTU/hour :

$$TCI = 7{,}850 \times (2{,}200/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers between 205 and 4,100 MMBTU/hour :

$$TCI = 10{,}530 \times (1{,}640/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers >5,500 MMBtu/hour:

$$TCI = 5{,}700 \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers >4,100 MMBtu/hour:

$$TCI = 7{,}640 \times Q_B \times ELEVF \times RF$$

| | | |
|---|---|---|
| Total Capital Investment (TCI) = | $4,000,366 | in 2021 dollars |

## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | | |
|---|---|---|
| Direct Annual Costs (DAC) = | $47,485 | in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $290,894 | in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $338,379 | in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

| | | | |
|---|---|---|---|
| Annual Maintenance Cost = | 0.005 x TCI = | $20,002 | in 2021 dollars |
| Annual Reagent Cost = | $m_{sol} \times Cost_{reag} \times t_{op}$ = | $2,217 | in 2021 dollars |
| Annual Electricity Cost = | $P \times Cost_{elect} \times t_{op}$ = | $10,810 | in 2021 dollars |
| Annual Catalyst Replacement Cost = | $n_{scr} \times Vol_{cat} \times (CC_{replace}/R_{layer}) \times FWF$ | $14,456 | in 2021 dollars |
| Direct Annual Cost = | | $47,485 | in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | | |
|---|---|---|---|
| Administrative Charges (AC) = | 0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) = | $2,868 | in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $288,026 | in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $290,894 | in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | | |
|---|---|---|
| Total Annual Cost (TAC) = | $338,379 | per year in 2021 dollars |
| NOx Removed = | 7 | tons/year |
| Cost Effectiveness = | $46,698 | per ton of NOx removed in 2021 dollars |

## Boiler 6,7 (EU-6,7)
## SNCR Design Parameters

**The following design parameters for the SNCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.**

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| Maximum Heat Input Rate ($Q_B$) = | HHV x Max. Fuel Rate = | 120 | MMBtu/hour | |
| Baseline $NO_X$ Emissions = | Average of 2020-2021 observed emissions | 8.20 | tons/year | |
| Unit Heat Input Rate = | Average of 2020-2021 heat input | 159,266 | MMBtu/year | |
| Controlled $NO_X$ Emissions Rate = | | 0.060 | lb/MMBtu | |
| Controlled $NO_X$ Emissions = | | 4.78 | tons/year | |
| Total $NO_x$ removed per year = | ** See Footnote | 3.42 | tons/year | |
| Coal Factor ($Coal_F$) = | 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends) | | | Not applicable; factor applies only to coal-fired boilers |
| $SO_2$ Emission rate = | $(\%S/100)x(64/32)*(1x10^6)/HHV$ = | | | Not applicable; factor applies only to coal-fired boilers |
| Elevation Factor (ELEVF) = | 14.7 psia/P = | | | Not applicable; elevation factor does not apply to plants located at elevations below 500 feet. |
| Atmospheric pressure at 25 feet above sea level (P) = | $2116x[(59-(0.00356xh)+459.7)/518.6]^{5.256}$ x (1/144)* = | 14.7 | psia | |
| Retrofit Factor (RF) = | Retrofit to existing boiler | 1.00 | | |

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

** Formula for NOx removed was overwritten to be consistent with methodology for LNB and PGR calculations.

**Reagent Data:**

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 lb/gallon

| Parameter | Equation | Calculated Value | Units |
|---|---|---|---|
| Reagent consumption rate ($m_{reagent}$) = | $(NOx_{in}$ x $Q_B$ x NSR x $MW_R)/(MW_{NOx}$ x SR) =<br>(whre SR = 1 for $NH_3$; 2 for Urea) | 5 | lb/hour |
| Reagent Usage Rate ($m_{sol}$) = | $m_{reagent}/C_{sol}$ = | 16 | lb/hour |
| | ($m_{sol}$ x 7.4805)/Reagent Density = | 2.2 | gal/hour |
| Estimated tank volume for reagent storage = | ($m_{sol}$ x 7.4805 x $t_{storage}$ x 24 hours/day)/Reagent Density = | 800 | gallons (storage needed to store a 14 day reagent supply rounded up to the nearest 100 gallons) |

**Capital Recovery Factor:**

| Parameter | Equation | Calculated Value |
|---|---|---|
| Capital Recovery Factor (CRF) = | $i(1+i)^n/(1+i)^n - 1$ =<br>Where n = Equipment Life and i= Interest Rate | 0.0720 |

| Parameter | Equation | Calculated Value | Units | |
|---|---|---|---|---|
| **Electricity Usage:**<br>Electricity Consumption (P) = | (0.47 x $NOx_{in}$ x NSR x $Q_B$)/NPHR = | 0.7 | kW/hour | |
| **Water Usage:**<br>Water consumption ($q_w$) = | ($m_{sol}$/Density of water) x (($C_{stored}/C_{inj}$) - 1) = | 4 | gallons/hour | |
| **Fuel Data:**<br>Additional Fuel required to evaporate water in injected reagent (ΔFuel) = | Hv x $m_{reagent}$ x $((1/C_{inj})-1)$ = | 0.04 | MMBtu/hour | |
| **Ash Disposal:**<br>Additional ash produced due to increased fuel consumption (Δash) = | (Δfuel x %Ash x $1x10^6$)/HHV = | 0.0 | lb/hour | Not applicable - Ash disposal cost applies only to coal-fired boilers |

# Boiler 6,7 (EU-6,7)
# SNCR Cost Estimate

## Total Capital Investment (TCI)

For Coal-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + APH_{cost} + BOP_{cost})$$

For Fuel Oil and Natural Gas-Fired Boilers:

$$TCI = 1.3 \times (SNCR_{cost} + BOP_{cost})$$

| | |
|---|---|
| Capital costs for the SNCR ($SNCR_{cost}$) = | \$529,153 in 2021 dollars |
| Air Pre-Heater Costs ($APH_{cost}$)* = | \$0 in 2021 dollars |
| Balance of Plant Costs ($BOP_{cost}$) = | \$795,466 in 2021 dollars |
| Total Capital Investment (TCI) = | \$1,722,005 in 2021 dollars |

#VALUE!

### SNCR Capital Costs ($SNCR_{cost}$)

For Coal-Fired Utility Boilers:

$$SNCR_{cost} = 220{,}000 \times (B_{MW} \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$SNCR_{cost} = 147{,}000 \times (B_{MW} \times HRF)^{0.42} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers:

$$SNCR_{cost} = 220{,}000 \times (0.1 \times Q_B \times HRF)^{0.42} \times CoalF \times BTF \times ELEVF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$SNCR_{cost} = 147{,}000 \times ((Q_B/NPHR) \times HRF)^{0.42} \times ELEVF \times RF$$

| | |
|---|---|
| SNCR Capital Costs ($SNCR_{cost}$) = | \$529,153 in 2021 dollars |

### Air Pre-Heater Costs ($APH_{cost}$)*

For Coal-Fired Utility Boilers:

$$APH_{cost} = 69{,}000 \times (B_{MW} \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

For Coal-Fired Industrial Boilers:

$$APH_{cost} = 69{,}000 \times (0.1 \times Q_B \times HRF \times CoalF)^{0.78} \times AHF \times RF$$

| | |
|---|---|
| Air Pre-Heater Costs ($APH_{cost}$) = | \$0 in 2021 dollars |

#VALUE!

### Balance of Plant Costs ($BOP_{cost}$)

For Coal-Fired Utility Boilers:

$$BOP_{cost} = 320{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Utility Boilers:

$$BOP_{cost} = 213{,}000 \times (B_{MW})^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

For Coal-Fired Industrial Boilers:

$$BOP_{cost} = 320{,}000 \times (0.1 \times Q_B)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times BTF \times RF$$

For Fuel Oil and Natural Gas-Fired Industrial Boilers:

$$BOP_{cost} = 213{,}000 \times (Q_B/NPHR)^{0.33} \times (NO_xRemoved/hr)^{0.12} \times RF$$

| | |
|---|---|
| Balance of Plant Costs ($BOP_{cost}$) = | \$795,466 in 2021 dollars |

# Boiler 6,7 (EU-6,7)
# SNCR Cost Estimate
## Annual Costs

**Total Annual Cost (TAC)**

TAC = Direct Annual Costs + Indirect Annual Costs

| | | |
|---|---|---|
| Direct Annual Costs (DAC) = | $28,576 | in 2021 dollars |
| Indirect Annual Costs (IDAC) = | $124,759 | in 2021 dollars |
| Total annual costs (TAC) = DAC + IDAC | $153,335 | in 2021 dollars |

**Direct Annual Costs (DAC)**

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Water Cost) + (Annual Fuel Cost) + (Annual Ash Cost)

| | | | |
|---|---|---|---|
| Annual Maintenance Cost = | 0.015 x TCI = | $25,830 | in 2021 dollars |
| Annual Reagent Cost = | $q_{sol}$ x $Cost_{reag}$ x $t_{op}$ = | $2,511 | in 2021 dollars |
| Annual Electricity Cost = | P x $Cost_{elect}$ x $t_{op}$ = | $66 | in 2021 dollars |
| Annual Water Cost = | $q_{water}$ x $Cost_{water}$ x $t_{op}$ = | $21 | in 2021 dollars |
| Additional Fuel Cost = | ΔFuel x $Cost_{fuel}$ x $t_{op}$ = | $147 | in 2021 dollars |
| Additional Ash Cost = | ΔAsh x $Cost_{ash}$ x $t_{op}$ x (1/2000) = | $0 | in 2021 dollars |
| Direct Annual Cost = | | $28,576 | in 2021 dollars |

**Indirect Annual Cost (IDAC)**

IDAC = Administrative Charges + Capital Recovery Costs

| | | | |
|---|---|---|---|
| Administrative Charges (AC) = | 0.03 x Annual Maintenance Cost = | $775 | in 2021 dollars |
| Capital Recovery Costs (CR)= | CRF x TCI = | $123,984 | in 2021 dollars |
| Indirect Annual Cost (IDAC) = | AC + CR = | $124,759 | in 2021 dollars |

## Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

| | | |
|---|---|---|
| Total Annual Cost (TAC) = | $153,335 | per year in 2021 dollars |
| NOx Removed = | 3 | tons/year |
| Cost Effectiveness = | $44,787 | per ton of NOx removed in 2021 dollars |

# APPENDIX E. QUOTE FOR BURNER REPLACEMENTS

## RACT PROJECT COSTS - BOILER NOS. 3 - 7 - 29 Jan22
### AOC 2022 CPP RACT ANALYSIS

| | BOILER NO. 3 | | BOILER NO. 4 | | BOILER NOS. 4 - 7 | |
|---|---|---|---|---|---|---|
| | LNB ($) | LNB & FGR ($) | LNB ($) | LNB & FGR ($) | LNB ($) | LNB & FGR ($) |
| **EQUIPMENT** | | | | | | |
| 1. BURNER | 1,050,000 | 1,100,000 | 200,000 | 225,000 | 800,000 | 900,000 |
| 2. FGR FAN | --- | 150,000 | --- | 25,000 | --- | 100,000 |
| SUBTOTAL | 1,050,000 | 1,250,000 | 200,000 | 250,000 | 800,000 | 1,000,000 |
| **DIRECT INSTALLATION** | | | | | | |
| 1. BURNER INSTALLATION | 80,000 | 80,000 | 20,000 | 20,000 | 80,000 | 80,000 |
| 2. FRONT WALL MODIFICATIONS | 60,000 | 60,000 | 30,000 | 30,000 | 120,000 | 120,000 |
| 3. GAS PIPING | 20,000 | 20,000 | 10,000 | 10,000 | 40,000 | 40,000 |
| 4. OIL PIPING | 20,000 | 20,000 | 10,000 | 10,000 | 40,000 | 40,000 |
| 5. BREACHING | --- | 100,000 | --- | 50,000 | --- | 200,000 |
| 6. CONTROL DAMPER | --- | 20,000 | --- | 15,000 | --- | 60,000 |
| 7. CONTROL WIRING | 40,000 | 50,000 | 20,000 | 25,000 | 80,000 | 100,000 |
| 8. CONTROL/ BMS INCORPORATION | 60,000 | 60,000 | 30,000 | 30,000 | 120,000 | 120,000 |
| 9. ELECTRICAL | 20,000 | 50,000 | 10,000 | 25,000 | 40,000 | 100,000 |
| SUBTOTAL | 300,000 | 460,000 | 130,000 | 215,000 | 520,000 | 860,000 |
| **INDIRECT INSTALLATION COSTS** | | | | | | |
| 1. ENGINEERING (10%) | 135,000 | 171,000 | 33,000 | 46,500 | 132,000 | 186,000 |
| 2. CONSTRUCTION ADMIN (4%) | 54,000 | 68,400 | 13,200 | 18,600 | 52,800 | 74,400 |
| 3. CONTRACTOR FEES (10%) | 135,000 | 171,000 | 33,000 | 46,500 | 132,000 | 186,000 |
| 4. START-UP (2%) | 27,000 | 34,200 | 6,600 | 9,300 | 26,400 | 37,200 |
| 5. CONTINGENCY (3%) | 40,500 | 51,300 | 9,900 | 13,950 | 39,600 | 55,800 |
| SUBTOTAL | 391,500 | 495,900 | 95,700 | 134,850 | 382,800 | 539,400 |
| **AOC REQUIRED INDIRECT COSTS** | | | | | | |
| 1. CONTINGENCY (20%) | 348,300 | 441,180 | 85,140 | 119,970 | 340,560 | 479,880 |
| 2. CONSTRUCTION ADMIN (4%) | 69,660 | 88,236 | 17,028 | 23,994 | 68,112 | 95,976 |
| 3. GOVERNMENT TEST AND Q/C (2.5%) | 43,538 | 55,148 | 10,643 | 14,996 | 42,570 | 59,985 |
| 4. AOC CONSTRUCTION MANAGEMENT (20%) | 348,300 | 441,180 | 85,140 | 119,970 | 340,560 | 479,880 |
| 5. AOC PM FEES (5%) | 87,075 | 110,295 | 21,285 | 29,993 | 85,140 | 119,970 |
| 6. OTHER (5%) | 87,075 | 110,295 | 21,285 | 29,993 | 85,140 | 119,970 |
| SUBTOTAL | 983,948 | 1,246,334 | 240,521 | 338,915 | 962,082 | 1,355,661 |
| GRAND TOTAL | 2,725,448 | 3,452,234 | 666,221 | 938,765 | 2,664,882 | 3,755,061 |

# APPENDIX F. DETAILED COST CALCULATIONS – ACTUAL EMISSIONS

This appendix contains detailed cost effectiveness calculations based on actual emissions for:

- Installing LNBs with FGR on Boiler 3
- Installing LNBs with FGR on Boilers 4 through 7

***U.S. Capitol Power Plant***
***Boiler 3 (CU-3)***
***Cost Analysis for Reducing $NO_X$ Emissions by Installing Low $NO_X$ Burners (LNB) and Flue Gas Recirculation (FGR)***

| Cost Item | Computational Method | Cost | Notes |
|---|---|---|---|
| *Purchased Equipment Costs* | | | |
| Burner | | $1,100,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| FGR Fan | | $150,000 | |
| Total Equipment Costs | | $1,250,000 (A) | |
| *Direct Installation Costs* | | | |
| Burner Installation | | $80,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Front Wall Modifications | | $60,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Gas Piping | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Oil Piping | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Breaching | | $100,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Damper | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Wiring | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control/BMS Incorporation | | $60,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Electrical | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $460,000 (B) | |
| Total Purchased Equipment and Direct | (A + B) | $1,710,000 (C) | |
| *Indirect Installation Costs* | | | |
| Engineering | 0.10 (C) | $171,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction and Field Expenses | 0.04 (C) | $68,400 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contractor Fees | 0.10 (C) | $171,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Start-up | 0.02 (C) | $34,200 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contingencies | 0.03 (C) | $51,300 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $495,900 (D) | |
| *AOC Required Indirect Installation Costs* | | | |
| Contingency | 0.20 (C + D) | $441,180 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction Admin | 0.04 (C + D) | $88,236 | Project Cost Estimate Provided by AEI dated January 2022. |
| Government Test and QC | 0.025 (C + D) | $55,148 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC Construction Management | 0.20 (C + D) | $441,180 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC PM Fees | 0.05 (C + D) | $110,295 | Project Cost Estimate Provided by AEI dated January 2022. |
| Other | 0.05 (C + D) | $110,295 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $1,246,334 (E) | |
| **Total Installed Capital Cost** | (C + D + E) | $3,452,234 (F) | |
| *Direct Annual Costs* | | N/A | |
| *Indirect Annual Costs* | | | |
| Capital Recovery | CRF (F) | $343,931 (G) | Reference EPA CCM 6th Edition, Section 1, Chapter 2, Equation2.8a. CRF based on 15 years and 5.5% interest rate. |
| **Total Annualized Cost** | (G) | $343,931 | |
| *Cost Effectiveness* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 13.3 | Baseline Actual Emissions is average of 2020-2021 observed emissions. |
| Unit Heat Input Rate (MMBtu/yr) | | 245,380 | Average heat input to boiler during 2020-2021 baseline. |
| Controlled $NO_X$ Emissions Rate (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(2)(B))[1] |
| Controlled $NO_X$ Emissions (tpy) | | 6.1 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 7.2 | |
| **Cost ($/ton $NO_X$ removed)** | | $47,732 | |

[1] To provide a conservative $NO_X$ removal cost estimate, the emissions limit for natural gas firing was used to calculate "controlled" emissions. However, this unit burns both fuel oil and natural gas during normal operations. Emissions during fuel oil firing would be subject to a limit of 0.12, resulting in fewer tons of $NO_X$ removed by this emissions control option and a higher $/ton cost.

***U.S. Capitol Power Plant***
***Boiler 4, 5, 6, or 7 (CU-4, 5, 6, or 7)***
***Cost Analysis for Reducing $NO_X$ Emissions by Installing Low $NO_X$ Burners (LNB) and Flue Gas Recirculation (FGR)***

| Cost Item | Computational Method | Cost | Notes |
|---|---|---|---|
| *Purchased Equipment Costs* | | | |
| Burner | | $225,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| FGR Fan | | $25,000 | |
| Total Equipment Costs | | $250,000 (A) | |
| *Direct Installation Costs* | | | |
| Burner Installation | | $20,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Front Wall Modifications | | $30,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Gas Piping | | $10,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Oil Piping | | $10,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Breaching | | $50,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Damper | | $15,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control Wiring | | $25,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Control/BMS Incorporation | | $30,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Electrical | | $25,000 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $215,000 (B) | |
| Total Purchased Equipment and Direct | (A + B) | $465,000 (C) | |
| *Indirect Installation Costs* | | | |
| Engineering | 0.10 (C) | $46,500 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction and Field Expenses | 0.04 (C) | $18,600 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contractor Fees | 0.10 (C) | $46,500 | Project Cost Estimate Provided by AEI dated January 2022. |
| Start-up | 0.02 (C) | $9,300 | Project Cost Estimate Provided by AEI dated January 2022. |
| Contingencies | 0.03 (C) | $13,950 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $134,850 (D) | |
| *AOC Required Indirect Installation Costs* | | | |
| Contingency | 0.20 (C + D) | $119,970 | Project Cost Estimate Provided by AEI dated January 2022. |
| Construction Admin | 0.04 (C + D) | $23,994 | Project Cost Estimate Provided by AEI dated January 2022. |
| Government Test and QC | 0.025 (C + D) | $14,996 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC Construction Management | 0.20 (C + D) | $119,970 | Project Cost Estimate Provided by AEI dated January 2022. |
| AOC PM Fees | 0.05 (C + D) | $29,993 | Project Cost Estimate Provided by AEI dated January 2022. |
| Other | 0.05 (C + D) | $29,993 | Project Cost Estimate Provided by AEI dated January 2022. |
| Total | | $338,915 (E) | |
| **Total Installed Capital Cost** | (C + D + E) | $938,765 (F) | |
| *Direct Annual Costs* | | N/A | |
| *Indirect Annual Costs* | | | |
| Capital Recovery | CRF (F) | $93,525 (G) | Reference EPA CCM 6th Edition, Section 1, Chapter 2, Equation2.8a. CRF based on 15 years and 5.5% interest rate. |
| **Total Annualized Cost** | (G) | $93,525 | |

***U.S. Capitol Power Plant***
***Boiler 4, 5, 6, or 7 (CU-4, 5, 6, or 7)***
***Cost Analysis for Reducing $NO_X$ Emissions by Installing Low $NO_X$ Burners (LNB) and Flue Gas Recirculation (FGR)***

| Cost Item | Computational Method | Cost | Notes |
|---|---|---|---|
| *Cost Effectiveness - Boiler 4* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 6.0 | Baseline Actual Emissions is average of 2020-2021 observed emissions. |
| Unit Heat Input Rate (MMBtu/yr) | | 114,915 | Average total heat input during 2020-2021 baseline. |
| Controlled $NO_X$ Emissions Rate (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(3)(C))[1] |
| Controlled $NO_X$ Emissions (tpy) | | 2.9 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 3.1 | |
| **Cost ($/ton $NO_X$ removed) - Boiler 4** | | $30,133 | |
| *Cost Effectiveness - Boiler 5* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 3.1 | Baseline Actual Emissions is average of 2020-2021 observed emissions. |
| Unit Heat Input Rate (MMBtu/yr) | | 57,745 | Average total heat input during 2020-2021 baseline. |
| Controlled $NO_X$ Emissions Rate (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(3)(C))[1] |
| Controlled $NO_X$ Emissions (tpy) | | 1.4 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 1.6 | |
| **Cost ($/ton $NO_X$ removed) - Boiler 5** | | $57,683 | |
| *Cost Effectiveness - Boiler 6* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 4.5 | Baseline Actual Emissions is average of 2020-2021 observed emissions. |
| Unit Heat Input Rate (MMBtu/yr) | | 89,337 | Average total heat input during 2020-2021 baseline. |
| Controlled $NO_X$ Emissions Rate (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(3)(C))[1] |
| Controlled $NO_X$ Emissions (tpy) | | 2.2 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 2.3 | |
| **Cost ($/ton $NO_X$ removed) - Boiler 6** | | $40,768 | |
| *Cost Effectiveness - Boiler 7* | | | |
| Baseline $NO_X$ Emissions (tpy) | | 3.7 | Baseline Actual Emissions is average of 2020-2021 observed emissions. |
| Unit Heat Input Rate (MMBtu/yr) | | 69,930 | Average total heat input during 2020-2021 baseline. |
| Controlled $NO_X$ Emissions Rate (lb/MMBtu) | | 0.05 | RACT limit for natural gas (20 DCMR 805.5(e)(3)(C))[1] |
| Controlled $NO_X$ Emissions (tpy) | | 1.7 | |
| Control Operating Time (%) | | 100% | |
| $NO_X$ Emissions Removed (ton/yr) | | 1.9 | |
| **Cost ($/ton $NO_X$ removed) - Boiler 7** | | $48,561 | |

[1] To provide a conservative $NO_X$ removal cost estimate, the emissions limit for natural gas firing was used to calculate "controlled" emissions. However, these units burn both fuel oil and natural gas during normal operations. Emissions during fuel oil firing would be subject to a limit of 0.09, resulting in fewer tons of $NO_X$ removed by this emissions control option and a higher $/ton cost.