TECHNICAL SUPPORT DOCUMENT FOR

PROPOSED RULEMAKING
ENVIRONMENTAL QUALITY BOARD
[25 PA. CODE CHS. 121 and 129]
ADDITIONAL RACT REQUIREMENTS FOR
MAJOR SOURCES OF NO_X AND VOCs FOR THE 2015 OZONE NAAQS
(RACT III)

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I. Introduction

The U.S. Environmental Protection Agency (EPA) is responsible for establishing National Ambient Air Quality Standards (NAAQS), which are maximum allowable concentrations in the ambient air for the following six pollutants: ground-level ozone; particulate matter; nitrogen dioxide (NO_2); carbon monoxide (CO); sulfur dioxide; and lead. These pollutants are identified as criteria pollutants by EPA and are considered harmful to public health and welfare, including the environment. Section 109 of the Clean Air Act (CAA) (42 U.S.C.A. § 7409) established two types of NAAQS: primary standards, which are limits set to protect public health; and secondary standards, which are limits set to protect public welfare and the environment, including protection against visibility impairment and from damage to animals, crops, vegetation and buildings. The EPA established primary and secondary ground-level ozone NAAQS to protect public health and welfare.

Ground-level ozone is formed in the atmosphere by photochemical reactions between volatile organic compounds (VOCs) and oxides of nitrogen (NO_X) in the presence of sunlight. In order to reduce ground-level ozone concentrations, the CAA (42 U.S.C.A. §§ 7401—7671q) requires control of sources of VOC and NO_X emissions to achieve emission reductions in nonattainment areas classified as “moderate” or higher. Among effective control measures, reasonably available control technology (RACT) air pollution controls significantly reduce VOC and NO_X emissions from major stationary sources. The CAA NO_X RACT requirements are described by the EPA in the “NO_X Supplement” notice titled, “State Implementation Plans; Nitrogen Oxides Supplement to the General Preamble; Clean Air Act Amendments of 1990 Implementation of Title I; Proposed Rule.” See 57 FR 55620 (November 25, 1992). In the NO_X Supplement notice, the EPA defined RACT as the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. *Id.* at 55624; See also 44 FR 53762 (September 17, 1979).

Section 110(a)(1) of the CAA (42 U.S.C.A. § 7410(a)) requires states to submit, within 3 years after promulgation of a new or revised standard, a state implementation plan (SIP) revision meeting the applicable requirements of section 110(a)(2). Re-evaluation of RACT is required each time a revised ozone NAAQS is promulgated for nonattainment areas. Section 172(c)(1) of the CAA (42 U.S.C.A. § 7502(c)(1)), requires states to develop nonattainment plan provisions “as expeditiously as practicable (including such reductions in emissions from existing sources in the area as may be obtained through the adoption, at minimum of [RACT]) to provide for the attainment of the [NAAQS].”

A major source in an ozone nonattainment area is defined as any stationary source that emits or has the potential to emit (PTE) NO_X or VOC emissions above a certain applicability threshold that is based on the ozone nonattainment classification of the area: marginal, moderate, serious, or severe. Sections 182(b)(2) and 182(f)(1) of the CAA (42 U.S.C.A. §§ 7511a(b)(2) and 7511a(f)(1)) require states with moderate, or worse, ozone nonattainment areas to implement RACT controls on all stationary sources and source categories covered by a control technique guideline (CTG) document issued by the EPA, and on all major sources of VOC and NO_X emissions located in the nonattainment area. The EPA's CTGs establish presumptive RACT control requirements for various VOC source categories. Presumptive RACT limits are category-wide requirements that are based on capabilities that are general to an emission source category. The CTGs typically identify a particular control level that the EPA recommends as RACT. In some cases, the EPA has issued Alternative Control Techniques (ACT) guidelines primarily for NO_X source categories, which in contrast to the CTGs, only present a range for possible control options but do not identify any particular option as the presumptive norm for what is RACT. States are required to implement RACT for the source categories covered by CTGs through a SIP. States may opt to require alternative controls rather than following the CTGs. See *Natural Resources Defense Council v. EPA*, 571 F.3d 1245, 1254 (D.C. Cir. 2009).

The CAA amendments of 1990 introduced the requirement for existing major stationary sources of NO_X in nonattainment areas to install and operate NO_X RACT. Specifically, section 182(b)(2) of the CAA requires states to adopt RACT provisions for all major sources of VOC in ozone nonattainment areas, and section 182(f) requires states to adopt RACT provisions for major stationary sources of NO_X.

Section 302 of the CAA (42 U.S.C.A. § 7602), defines a major stationary source (MSS) as any facility which has the PTE 100 tons per year (TPY) of any air pollutant. For serious ozone nonattainment areas, a major source is defined by section 182(c) of the CAA as a source that has the PTE 50 TPY of NO_X. For severe ozone nonattainment areas, a major source is defined by section 182(d) of the CAA as a source that has the PTE 25 TPY of any pollutant.

The Ozone Transport Region (OTR) has special provisions for major sources since section 184(a) of the CAA (42 U.S.C.A. § 7511c(a)) requires areas in the OTR to be treated as moderate (or higher) ozone nonattainment. Therefore, in marginal and moderate nonattainment areas and attainment areas in the OTR, a major NO_X source is one with the PTE 100 TPY or more of NO_X. Because the entire Commonwealth is in the OTR and is treated as a moderate nonattainment area, RACT is applicable to major sources of NO_X emissions or VOC emissions, or both, statewide.

II. 1971 Photochemical Oxidants NAAQS - 0.08 ppm and 1979 and 1993 Ozone NAAQS – 0.12 ppm, averaged over 1 hour (RACT I)

On April 30, 1971, the EPA promulgated primary and secondary NAAQS for photochemical oxidants under section 109 of the CAA. See 36 FR 8186 (April 30, 1971). These standards set an hourly average of 0.08 parts per million (ppm) total photochemical oxidants not to be exceeded more than 1 hour per year. On February 8, 1979, the EPA announced a revision to the then-current 1-hour standard. The final rulemaking revised the level of the primary 1-hour ozone standard from 0.08 ppm to 0.12 ppm and set the secondary standard identical to the primary standard. See 44 FR 8202 (February 8, 1979). This revised 1-hour standard was reaffirmed on March 9, 1993. See 58 FR 13008 (March 9, 1993).

Section 110(a) of the CAA gives states the primary responsibility for achieving the NAAQS. Section 110(a) of the CAA provides that each state shall adopt and submit to the EPA a plan to implement measures (a SIP) to enforce the NAAQS or a revision to the NAAQS promulgated under section 109(b) of the CAA. A SIP includes the regulatory programs, actions and commitments a state will carry out to implement its responsibilities under the CAA. Once approved by the EPA, a SIP is legally enforceable under both Federal and state law.

Section 182 of the CAA requires that, for areas that exceed the NAAQS for ozone, states shall develop and implement a program that mandates that certain major stationary sources develop and implement a RACT program. Under sections 182(f)(1) and 184(b)(2) of the CAA, these RACT requirements are applicable to all sources in Pennsylvania that emit or have a PTE emit greater than 100 TPY of NO_X. Under sections 182(b)(2) and 184(b)(2) of the CAA, these RACT requirements are applicable to all sources in Pennsylvania that emit or have a PTE greater than 50 TPY of VOCs. NO_X and VOC controls are required statewide because of the Commonwealth's inclusion in the OTR established by Congress under section 184(a) of the CAA. Additionally, because the five-county Philadelphia area was designated as severe ozone nonattainment for the 1-hour standard in 1979, sources of greater than 25 TPY of either pollutant were required to implement RACT under section 182(d) of the CAA.

Section 182(b)(2) of the CAA provides that for moderate ozone nonattainment areas, a state must revise its SIP to include RACT for sources of VOC emissions covered by a CTG document issued by the EPA prior to the area's date of attainment; sources of VOC emissions covered by a CTG issued prior to November 15, 1990; and all other major stationary sources of VOC emissions located in the area. The EPA has issued RACT determinations in the form of CTGs for approximately 25 to 30 classes of VOC sources. The CTGs cover many types of sources, including large graphic arts facilities, industrial surface coating operations, petroleum refineries and gasoline marketing terminals. The Department incorporated the requirements of these CTGs into regulatory standards of source-specific emission limitations. Several sources subject to RACT regulations were adopted to implement CTG. See 25 Pa. Code §§ 129.96(a) and (b). These regulations are codified in §§ 129.51—129.52c, 129.54—129.69, 129.71—129.73, 129.75, 129.77, 129.101—129.107 and 129.301—129.310.

The Commonwealth's RACT regulations under §§ 129.91—129.95 (relating to stationary sources of NO_X and VOCs) were implemented statewide in January 1994 for the 1979 and 1993 1-hour ozone standard. See 24 Pa.B. 467 (January 15, 1994). These regulations imposed a requirement that the owners and operators of sources and facilities emitting VOCs and NO_X determine if they are MSS of VOCs or NO_X, or both. If a facility is a MSS, the owner or operator must develop and submit a RACT proposal to the Department and to the EPA for approval. Sources subject to the EPA's New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP) are required to comply with all applicable requirements including emission limits that are more stringent than RACT limits.

The final amendments also authorized implementation of presumptive NO_X RACT requirements for three major classes of NO_X emitters. The owners and operators of small industrial boilers were required to make appropriate adjustments to the combustion process to minimize NO_X emissions. The owners and operators of small combustion units and certain other classes of fossil-fuel-burning equipment (<20 million Btu/hour) were required to operate the source in accordance with the manufacturer's specifications. The owners and operators of larger combustion units (equal to or greater than 20 million Btu/hour to < 50 million Btu/hour) were required to perform an annual tune-up and make adjustments to provide for a low NO_X emitting operation; and the owners and operators of very large coal-fired combustion units (equal to or greater than 100 million Btu/hour) were required to install a low NO_X burner system with separated overfire air (LNB-SOFA). See 25 Pa. Code § 129.93.

On February 1, 1994, the Department developed guidance (Appendix 1) for submitting RACT proposals for major NO_X sources which were required to determine the RACT for NO_X emissions on a case-by-case basis. The guidance recommends that the RACT analysis should include a ranking of all applicable and available control technologies for the affected sources in descending order of control effectiveness. The applicant should examine the most stringent or "top" alternative. If the applicant could show that this level of control for the source under review is technically or economically infeasible based on the EPA's Office of Air Quality Planning and Standards (OAQPS) Control Cost Manual, then the next most stringent level of control is determined and similarly evaluated. The analysis continues until the RACT level under consideration cannot be eliminated by any substantial or unique technical or economical objection.

In the guidance document, the Department indicated that most states have included presumptive limits for NO_X emissions in their regulations and control measures available to achieve these levels show a range of cost-effectiveness from about \$570 - \$1,500 per ton of NO_X removed. The guidance document also indicated that technologies available to meet the EPA's preliminary presumptive RACT levels for electric utility boilers show a range of cost-effectiveness from about \$160 – \$1,300 per ton of NO_X removed. The EPA document "Evaluation and Costing of NOx Controls for Existing Utility Boilers in the NESCAUM Region," [EPA 453/R-92-010] shows that the control costs for Low NO_X Burner with Separate Overfire Air (LNB-SOFA) vary from \$270 to \$1,590 per ton of NO_X removed depending on site-specific factors (such as the type of boiler, size of the boiler and the amount of use) (Appendix 2). The control measures available to achieve the levels established as presumptive RACT for utility boilers by other states show a range of cost-effectiveness from about \$570 - \$1,500 per ton. Two NO_X RACT proposals using LNB-SOFA document costs of \$1,222 and \$1,298 per ton of NO_X reduced.

Based on the above information, the Department utilized \$1,500 per ton of NO_X reduced as a benchmark to consider the control option to be cost-effective. The Department suggested using \$1,500 as a benchmark because it was comparable, but lower than the control cost for sources of VOCs (the other major ozone precursor) to comply with existing RACT regulations based on EPA's guidelines. For VOCs, the cost-effectiveness benchmark of \$3,000 per ton of VOC removed was used.

Under §§ 129.91—129.95, approximately 600 facilities case-by-case RACT determinations were made for attaining and maintaining the 1-hour ozone standard and were submitted to the EPA as RACT SIP revisions. The case-by-case analysis process began in 1995 and was not completed until 2006 due to the need for EPA approval of SIP submittals for the case-by-case RACT determinations. Many facility owners and operators had to hire consultants or additional staff to complete their case-by-case RACT analyses and proposals and handle the permitting requirements.

III. 1997 Ozone NAAQS – 0.08 ppm and 2008 Ozone NAAQS - 0.075 ppm, averaged over 8 hours (RACT II)

On July 18, 1997, the EPA concluded that revisions to the then-current 1-hour ozone primary standard to provide increased public health protection were appropriate at this time to protect public health with an adequate margin of safety. Further, the EPA determined that it was appropriate to establish a primary standard of 0.08 ppm averaged over 8 hours. The EPA at this time also established a secondary standard equal to the primary standard. See 62 FR 38856 (July 18, 1997). In 2004, the EPA designated 37 counties in Pennsylvania as 8-hour ozone nonattainment areas for the 1997 8-hour ozone NAAQS. See 69 FR 23858, 23931 (April 30, 2004).

On March 27, 2008, the EPA lowered the primary and secondary 8-hour ozone standards from 0.08 ppm to 0.075 ppm. See 73 FR 16436 (March 27, 2008). The EPA made designations for the 2008 8-hour ozone standards on April 30, 2012, with an effective date of July 20, 2012. The EPA designated all or portions of Allegheny, Armstrong, Beaver, Berks, Bucks, Butler, Carbon, Chester, Delaware, Fayette, Lancaster, Lehigh, Montgomery, Northampton, Philadelphia, Washington and Westmoreland counties as nonattainment for the 2008 8-hour ozone NAAQS, with the rest of Pennsylvania designated as unclassifiable/attainment. See 77 FR 30088, 30143 (May 21, 2012). The EPA's 2008 ozone implementation rule required the Department to submit a SIP revision that met the RACT requirements of CAA section 184(b)(2) for the entire Commonwealth. See 40 CFR 51.1112 and 51.1116.

Pennsylvania's RACT regulations under §§ 129.96—129.100 (relating to additional RACT requirements for major sources of NO_X and VOCs) (RACT II) were implemented in April 2016, for the 1997 and 2008 8-hour ozone standards. See 46 Pa.B. 2036 (April 23, 2016). EPA issued a partial approval and conditional approval of Pennsylvania's RACT II regulations on May 9, 2019 (84 FR 20274). The final rulemaking established applicability requirements for the implementation of specified RACT control measures for the nine identified source types for attaining and maintaining the 1997 and 2008 8-hour ozone standards. The Department used a top-down approach to determine presumptive NO_X and VOC RACT emissions limits for various source categories. This included searching and identifying the best methodology, technique, technology or other means for reducing NO_X or VOC emissions, while factoring environmental, energy and economic considerations into the analysis. The Department contacted various vendors, reviewed EPA's CTGs and ACTs documents. The Department also identified controls installed on existing air contaminant sources in Pennsylvania and identical air contaminant sources in other states. The Department estimated the capital, installation and annual operating costs using the EPA's OAQPS and Control Cost Manual (Sixth edition), vendor's quotes, as well as input from independent entities such as PJM Interconnection.

The Department used a specific dollar value per ton of NO_X or VOC reduced as a benchmark to consider a specific control's cost-effectiveness. In the absence of guidance for cost-effectiveness benchmark cut-off limits during the RACT II development, the Department determined the cost-effectiveness benchmark number based on the EPA's approved cost-effectiveness benchmark values in the 1990 RACT implementation and used the Consumer Price Index (CPI) to calculate the new cost-effectiveness benchmarks. The Department evaluated various NO_X and VOC controls for technical and economical feasibility. The Department did not establish a bright-line cost-effectiveness threshold to determine economic feasibility for RACT II implementation. The Department had used cost-effectiveness benchmarks of $1,500 and $3,000 per ton of NO_X and VOC controlled, respectively, in 1990 dollars, for the implementation of RACT I requirements for the 1979 1-hour ozone NAAQS in §§ 129.91—129.95. The Department used the United States Bureau of Labor Statistics CPI and adjusted the $1,500 in 1990 dollars to $2,754 in 2014 dollars. The Department used a NO_X emission cost-effectiveness upper bound of $2,800 per ton of NO_X emissions controlled and $5,500 per ton of VOC emissions controlled.

Based on the uncontrolled emission rates and control efficiency of technically and economically feasible control option, the Department determined the presumptive RACT II emission limits for NO_X and VOCs. The RACT II final rulemaking also incorporated operational flexibility including the option to request approval to use facility-wide or system-wide NO_X emissions averaging, a source-specific NO_X or VOC emission limitation, or source-specific RACT NO_X or VOC requirement as alternative methods of compliance. See, 25 Pa. Code §§ 129.98-129.99.

The Department determined that certain add-on control technologies represented RACT for the 1997 and 2008 8-hour ozone NAAQS for nine existing source categories that did not have presumptive RACT requirements or emission limitations in Chapter 129. These nine source categories included combustion units; boilers; process heaters; turbines; stationary internal combustion engines; municipal solid waste landfills; municipal waste combustors; cement kilns; and certain other sources that were not regulated elsewhere under Chapter 129. RACT II final-form rulemaking amended Chapter 129 to adopt presumptive RACT requirements and RACT emission limitations for certain major stationary NO_X and VOC emissions that were subject to § 129.96. See 25 Pa. Code § 129.97.

IV. 2015 Ozone NAAQS - 0.070 ppm averaged over 8 hours (RACT III)

On October 26, 2015, the EPA lowered the primary and secondary 8-hour ozone standards from 0.075 ppm to 0.070 ppm. See 80 FR 65292 (October 26, 2015). The EPA issued the 2015 ozone implementation rule on December 6, 2018 (83 FR 62998). See, 40 CFR 51.1306—51.1318. The EPA's 2015 ozone implementation rule required the Department to submit a SIP revision that met the RACT requirements of CAA section 184(b)(2) for the entire Commonwealth. See 40 CFR 51.1312 and 51.1316.

On *******, 2021 [Date of publication], the Environmental Quality Board proposed to amend Chapters 121 and 129 (relating to general provisions; and standards for sources) with additional RACT requirements for major sources of NO_X and VOCs for the 2015 ozone NAAQS. The amendments to § 121.1 and the substantive provisions in §§ 129.111—129.115 are proposed to implement the RACT requirements for the 2015 8-hour ozone NAAQS.

(A) Applicability:

The RACT III regulation would be applicable to any owner or operator of a "major NO_X-emitting facility" or a "major VOC-emitting facility," or both, in the Commonwealth, that existed on or before August 3, 2018.

Owners and operators of facilities that are major facilities solely for NO_X emissions are only subject to the NO_X RACT requirements. Likewise, owners and operators of facilities that are major facilities solely for VOC emissions are only subject to the VOC RACT requirements. The statewide RACT III applicability thresholds for NO_X and VOC are 100 and 50 TPY, respectively.

The RACT III regulation does not apply to sources that have a PTE less than one ton of NO_X and/or VOC, as applicable, on a 12-month rolling basis. [25 Pa. Code § 129.111]

Section 182(b)(2) of the CAA (42 U.S.C.A. § 7511a(b)(2)) provides that for moderate ozone nonattainment areas, a state must revise its SIP to include RACT for sources of VOC emissions covered by a CTG document issued by the EPA prior to the area's date of attainment; sources of VOC emissions covered by a CTG issued prior to November 15, 1990; and all other major stationary sources of VOC emissions located in the area.

The EPA has issued RACT determinations in the form of CTGs for various classes of VOC sources. The CTGs cover many types of sources, including large graphic arts facilities, industrial surface coating operations, petroleum refineries and gasoline marketing terminals. The Department has incorporated the requirements of these CTGs into regulatory standards of source-specific emission limitations.

Sources subject to regulations are adopted to implement Control Technique Guidelines (CTG) [25 Pa. Code §§ 129.96(a) and (b)]. These regulations are codified in 25 Pa. Code §§ 129.51—129.52c, 129.54—129.69, 129.71—129.73, 129.75, 129.77, and 129.101—129.107.

Sources subject to EPA's NSPS and NESHAP are required to comply with all applicable requirements including emission limits that are more stringent than RACT limits.

(B) Presumptive RACT source categories:

It is not possible to provide a specific and precise presumptive NO_X or VOC emission limit for each specific source, or estimate the control costs that may incur by the owner or operator, due to a wide range of source types, their size, fuel-burned and operating characteristics. Therefore, the Department has categorized the existing and affected sources into various source categories to evaluate, analyze and determine the presumptive RACT NO_X and/or VOC emission limits and requirements. These categories include combustion units; municipal solid waste landfills; municipal waste combustors; process heaters; turbines; stationary internal combustion engines; cement kilns; glass melting furnace; lime kiln; direct-fired heater, furnace or oven; and other sources that are not regulated elsewhere under Chapter 129.

The Department used a top-down approach in determining presumptive NO_X and/or VOC RACT emissions limits for various source categories. This included searching and identifying the reasonably available controls, methodology, technique, technology or other means for reducing NO_X or VOC emissions, while factoring technical and economic feasibility considerations into the analysis. The Department reviewed EPA guidance documents about air pollution control technologies and associated costs, contacted various vendors for estimated costs for specific technologies, and neighboring states to learn about their proposed RACT III regulations.

The Department evaluated NO_X Control technologies such as Low NO_X Burner, Dry Low NO_X Combustor, Low Emission Combustion, Selective Catalytic Reduction , Selective Non-Catalytic Reduction, Non-Selective Catalytic Reduction and a VOC control technology, Oxidation Catalyst.

Low NO_X Burner (LNB): Low NO_X burners reduce NO_X by accomplishing the combustion process in stages. Staging partially delays the combustion process, resulting in a cooler flame which suppresses thermal NO_X formation. The two most common types of low NO_X burners being applied to natural gas-fired boilers are staged air burners and staged fuel burners. LNB retrofits typically achieve NO_X reduction in the range of 50 percent.

Dry Low NOx Combustor (DLNC): This technology involves increasing the air-to-fuel ratio of the mixture so that the peak and average temperatures within the combustor will be less than that of the stoichiometric mixture, thus suppressing thermal NO_X formation. Introducing excess air not only creates a leaner mixture but it also can reduce residence time at peak temperatures. NO_X emissions reductions of up to 30 percent are achieved using lean primary zone combustion without increasing CO emissions.

Low Emission Combustion (LEC): NO_X emissions from natural gas combustion are formed from nitrogen and oxygen in the combustion air, and NO_X emissions increase significantly at higher combustion temperatures. LEC achieves lower NO_X by providing sufficient excess air to reduce the maximum combustion temperature and minimize NO_X formation. Engine manufacturers and regulatory agencies use the term "LEC" broadly and a number of technology approaches can be used depending on the engine and NO_X emission limit. In many cases, multiple LEC related technologies may be required (e.g., additional air through new or upgraded turbocharging, higher energy ignition/pre-combustion chambers, and enhanced mixing). NO_X emissions reductions of 30 to 50 percent are achieved using lean primary zone combustion without increasing CO emissions.

Selective Catalytic Reduction (SCR): SCR systems selectively reduce NO_X emissions by injecting ammonia (NH_3) into the exhaust gas stream upstream of a catalyst. NO_X, NH_3 and oxygen (O_2) react on the surface of the catalyst to form nitrogen (N_2) and water (H_2O). The exhaust gas must contain a minimum amount of O2 and be within a particular temperature range (typically 450 °F to 850 °F) in order for the SCR system to operate properly. The temperature range is dictated by the catalyst material which is typically made from noble metals, including base metal oxides such as vanadium and titanium, or zeolite-based material. The removal efficiency of an SCR system in good working order is typically from 65 to 90 percent. Exhaust gas temperatures greater than the upper limit (850 °F) cause NO_X and NH_3 to pass through the catalyst unreacted. Ammonia emissions, called NH_3 slip, may be a consideration when specifying an SCR system.

Selective Noncatalytic Reduction (SNCR): SNCR is a post combustion emissions control technology for reducing NO_X by injecting ammonia or urea into the furnace at a properly determined location without the need of a catalyst. Units with furnace exit temperatures of 1550-1950 °F, residence times of greater than one second, and high levels of uncontrolled NO_X are required for higher control efficiencies. SNCR reduction efficiencies vary over a wide range. Temperature, residence time, type of NO_X reducing reagent, reagent injection rate, uncontrolled NO_X level, distribution of the reagent in the flue gas, and CO and O_2 concentrations all affect the reduction efficiency of the SNCR. The median (as a measure of average) reductions for urea-based SNCR systems in various industry source categories range from 25 to 60 percent, while median reductions for ammonia-based SNCR systems range from 61 to 65 percent.

Nonselective Catalytic Reduction (NSCR): This technique uses the residual hydrocarbons and CO in the rich-burn engine exhaust as a reducing agent for NO_X. In an NSCR, hydrocarbons and CO are oxidized by O_2 and NO_X. The excess hydrocarbons, CO, and NO_X pass over a catalyst (usually a noble metal such as platinum, rhodium, or palladium) that oxidizes the excess hydrocarbons and CO to H_2O and CO_2, while reducing NO_X to N2. NO_X reduction efficiencies are usually greater than 90 percent, while CO reduction efficiencies are approximately 90 percent. The NSCR technique is effectively limited to engines with normal exhaust oxygen levels of 4 percent or less. This includes 4-stroke rich-burn naturally aspirated engines and some 4-stroke rich-burn turbocharged engines. Engines operating with NSCR require tight air-to-fuel control to maintain high reduction effectiveness without high hydrocarbon emissions. To achieve effective NO_X reduction performance, the engine may need to be run with a richer fuel adjustment than normal. This exhaust excess oxygen level would probably be closer to 1 percent. Lean-burn engines could not be retrofitted with NSCR control because of the reduced exhaust temperatures.

Oxidation Catalyst: Oxidation catalysts (or two-way catalytic converters) are used to reduce hydrocarbon and CO emissions. Specifically, oxidation catalysts are effective for the control of CO, non-methane hydrocarbons, VOCs, formaldehyde and other Hazardous Air Pollutants. Oxidation catalysts consist of a substrate made up of thousands of small channels. Each channel is coated with a highly porous layer containing precious metal catalysts, such as platinum or palladium. As exhaust gas travels down the channel, hydrocarbons and CO react with oxygen within the porous catalyst layer to form CO_2 and water vapor. The resulting gases then exit the channels and flow through the rest of the exhaust system. Using an oxidation catalyst, VOC emissions can be reduced by 50 to 60 percent.

The Department then ranked all available control technologies in the order of their control effectiveness. After finding the most effective controls in the list, the Department evaluated the most stringent control for technical and economic feasibility. The Department eliminated the most stringent control and analyzed second control in the list if the most stringent control was determined to be technically infeasible or economically cost-prohibitive. The Department then reviewed the existing allowable NO_X or VOC emissions limits or actual test data to establish a baseline emission to determine economic feasibility for emission controls for the proposed RACT III regulation.

The Department then conducted a generic cost analysis for sources in each source category subject to presumptive NO_X and/or VOC RACT emissions limits to determine if additional NO_X and/or VOC controls would represent RACT for the 8-hour 2015 ozone NAAQS. The

Department performed cost analysis using guidance provided in the EPA Air Pollution Control Cost Manual, EPA/452/B-02- 001, 6th edition, January 2002 and 7th edition, vendor's quote, and cost data compiled from previous installations inside and outside of Pennsylvania. The cost analysis includes the total capital investment of the add-on control equipment, the annual operating costs of the add-on control, and the cost-effectiveness of the control in reducing emissions from the source. Capital investments include costs associated with purchased equipment, installation, monitoring equipment, delivery, start-up and initial testing and taxes. Direct annual costs include the costs of electricity or fuel to operate the add-on control and the monitoring equipment, if needed, maintenance and repair costs. Indirect annual costs include overhead, administrative cost, property taxes, insurance and capital recovery cost. As per EPA's guidance in Control Cost Manual 7th edition (revised in 2019) the department used equipment life for SCR at 30 years, for SNCR and other control equipment at 20 years and an annual interest rate of 5.5 percent to calculate the capital recovery factor. The capital recovery factor is added to the annual cost to determine annualized cost. The cost-effectiveness of the control is calculated by dividing the annualized costs of the add-on control by the amount of emission reductions achieved annually from operation of the add-on control.

The Department adjusted the RACT II cost benchmarks of \$2,800 and \$5,500 per ton of NO_X or VOC emissions removed, respectively, by multiplying by the CPI differential between 2014 and 2020 to arrive at benchmarks of \$3,000 and \$6,000 per ton of NO_X or VOC emissions removed, respectively, for RACT III. The Department further adjusted cost-effectiveness benchmarks to to \$3,750 per ton of NO_X and \$7,500 per ton of VOC to ensure the implementation of RACT level controls similar to what was done for RACT II. See 46 Pa.B. 2044 (April 23, 2016). The Department concludes that the RACT presumptive limits included in the proposed RACT III Rule are reasonable as they reflect control levels achieved by the application and consideration of available control technologies, after considering both the economic and technological circumstances of Pennsylvania's sources. It should be noted that for the proposed Cross-State Air Pollution (CSAPR) rule, EPA used a control stringency level set at a marginal cost of \$1,600 per ton of NO_X emission reductions to identify a uniform NO_X emission control stringency level at which EPA determines maximum cost-effective EGU NO_X emission reductions and downwind ozone air quality improvements. See 85 FR 68964 (October 30, 2020). Using these cost benchmarks as a guide, the Department evaluated technically feasible emission controls for cost-effectiveness and economic feasibility. The RACT III NO_X and VOC emission limitations included in this proposed rulemaking were determined from this evaluation.

Based on the uncontrolled emission rates and control efficiency of technically and economically feasible control option, the Department determined the presumptive RACT emission limits for NO_X and VOCs. The Department also compared these RACT emissions limits established by other states for identical sources.

Compliance costs may vary for each source or facility depending on the source size, type, operation limitation and which control option is selected by the owner and operator of the affected source or facility. An owner or operator of an affected source that cannot meet applicable presumptive RACT emission limitation, may participate in either a facility-wide or system-wide NO_X emissions averaging program or propose an alternative NO_X or VOC emission limitations or requirements, both, on a case-by-case basis.

(C) RACT analysis and proposed NO_X and VOC RACT emission limits for small source category:

Combustion units with a rated heat input equal to or greater than 20 million Btu/hour and less than 50 million Btu/hour:

The Department evaluated LNB technology for NO_X reduction and oxidation catalyst technology for VOC reduction for combustion units with a rated heat input equal to or greater than 20 million Btu/hour and less than 50 million Btu/hour that range $3,536 - $8,841 per ton of NO_X removed and $260,750 - $651,876 per ton of VOC removed. (Appendix 3)

Therefore, the Department is proposing that existing biennial tune-up requirements in accordance with 40 CFR Part 63 Subpart 63.11223 continue to represent RACT for the existing combustion unit with a rated heat input equal to or greater than 20 million Btu/hour and less than 50 million Btu/hour. [25 Pa. Code § 129.112(b)(i)]

Insignificant NO_X and VOC emitting source categories:

The Department evaluated LNB, SCR and SNCR technologies for NO_X reduction and oxidation catalyst technology for VOC reduction.

The Department performed cost-effectiveness analysis for a 50 million Btu/hour combustion unit with uncontrolled NO_X emission rate of 5.0 TPY using reference costs data for LNB and found the cost-effectiveness at $30,981 per ton of NO_X removed. The Department also performed cost-effectiveness analysis for oxidation catalyst technology for a 50 million Btu/hour combustion unit with uncontrolled NO_X emission rate of 2.7 TPY using reference costs data for oxidation catalyst and found the cost-effectiveness at $76,139 per ton of VOC removed. (Appendix 4)

Based on the above cost analysis the Department determined that NO_X and VOC emitting sources with NO_X and VOC emissions thresholds of 5 TPY and 2.7 TPY, respectively, with no add-on or inherent NO_X or VOC controls continue to be economically feasible.

Therefore, the Department is proposing that the source categories below shall continue to comply with the existing presumptive RACT requirements of installation, maintenance, and operation of the source in accordance with manufacturer's specifications and with good operating practices. [25 Pa. Code § 129.112(c)].

NO_X source with a PTE of less than 5 TPY of NO_X.

VOC source with a PTE of less than 2.7 TPY of VOC.

A boiler or other combustion source rated < 20 million British Thermal Units per hour (million Btu/hour).

A combustion turbine rated < 1,000 brake horsepower (bhp).

A lean burn or rich burn stationary internal combustion engine rated < 500 bhp (gross).

An incinerator, thermal oxidizer or catalytic oxidizer used primarily for air pollution control.

A fuel-burning unit with an annual capacity factor of less than 5%.

An emergency engine operating less than 500 hours per year in a 12-month rolling period.

An electric arc furnace.

A natural gas compression and transmission facility VOC air contamination source that has the potential to emit less than 2.7 TPY of VOC.

For natural gas compression and transmission facilities, a fugitive VOC air contamination source is the group of fugitive VOC emitting components associated with an individual stationary source. Each group of components is considered as an individual VOC emitting source and the VOC emissions from the components are not aggregated with the VOC emissions from the associated stationary source.

A combustion unit, brick kiln, cement kiln, lime kiln or other combustion source located at a major VOC emitting facility shall install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices for the control of the VOC emissions from the combustion unit or other combustion source. [25 Pa. Code § 129.112(d)]

(D) Municipal Solid Waste Landfills:

The Department is proposing that the owner and operator of a municipal solid waste (MSW) landfill constructed, reconstructed or modified on or before May 29, 1991, shall comply with the emission guidelines in 40 CFR Part 60, Subpart Cc. The control of collected MSW landfill emissions through the use of control devices meeting at least one of the following provisions: (1) An open flare designed and operated in accordance with the parameters established in § 60.18; or (2) A control system designed and operated to reduce non-methane organic compounds (NMOC) by 98 weight percent; or (3) An enclosed combustor designed and operated to reduce the outlet NMOC concentration to 20 ppm as hexane by volume, dry basis at 3% oxygen, or less. These control requirements are consistent with §60.33c and are adopted and incorporated by reference in §122.3, and the applicable Federal or state plans in 40 CFR Part 62. [25 Pa. Code § 129.112(e)(1)]

The Department is proposing that the owner and operator of a MSW landfill constructed, reconstructed or modified on or after May 30, 1991, but on or before July 17, 2014, shall comply with the New Source Performance Standards in 40 CFR Part 60, Subpart WWW (relating to standards of performance for municipal solid waste landfills) or the more stringent Subpart Cf. The control of collected MSW landfill emissions through the use of control devices meeting at least one of the following provisions: (1) An open flare designed and operated in accordance with the parameters established in § 60.18; or (2) A control system designed and operated to reduce NMOC by 98 weight percent; or (3) An enclosed combustor designed and operated to reduce the outlet NMOC concentration to 20 ppm as hexane by volume, dry basis at 3% oxygen, or less. These control requirements are consistent with § 60.752 and § 60.33f and are adopted and incorporated by reference in §122.3. [25 Pa. Code § 129.112(e)(2)]

Therefore, the existing requirements continue to represent RACT.

The Department is also proposing that the owner and operator of a MSW landfill constructed, reconstructed or modified on or after July 18, 2014, shall comply with the New Source Performance Standards in 40 CFR Part 60, Subpart XXX (relating to standards of performance for municipal solid waste landfills). The control of collected MSW landfill emissions through the use of control devices meeting at least one of the following provisions: (1) An open flare designed and operated in accordance with the parameters established in § 60.18; or (2) A control system designed and operated to reduce NMOC by 98 weight percent; or (3) An enclosed combustor designed and operated to reduce the outlet NMOC concentration to 20 ppm as hexane by volume, dry basis at 3% oxygen, or less. These control requirements are consistent with § 60.762 and are adopted and incorporated by reference in § 122.3, and which are adopted and incorporated by reference in § 122.3. [25 Pa. Code § 129.112(e)(3)]

(E) Municipal Waste Combustors:

Region-wide, several states have proposed or revised NO_X RACT standards for Large Municipal Waste Combustors (MWCs). New Jersey adopted regulation that established a NO_X RACT emission rate of 150 parts per million by volume, dry basis (ppmvd) as determined on a calendar day average. Massachusetts and Maryland established a NO_X RACT of 150 ppmvd for large MWCs. Connecticut adopted a 150 ppm limit for mass burn waterwall combustors on a 24-hour daily average. The Department evaluated SCR technology for combustors firing municipal waste and found that performance of SCR can be detrimentally affected if the catalyst becomes de-activated due to poisoning or masking. Catalyst poisoning can occur if the catalyst is exposed to sufficient amounts of certain heavy metals that are present in the flue gas, as a result of MSW combustion. Catalyst masking can occur when the catalyst surface becomes coated with a foreign material, preventing the flue gas from physically coming into contact with the catalyst. The Department also evaluated whether any existing MWCs in OTR are equipped with SCR, but couldn't find any. Therefore, the Department determined that adding SCR NO_X emission control technology would likely not be considered RACT because of its technical infeasibility.

The Department evaluated cost-effectiveness for SNCR using estimated 500 tons per day throughput and using reference cost data from other MWC. The Department found that the cost-effectiveness to retrofit SNCR for MWC with 150 ppmvd corrected at 7% oxygen yields over $3,946 per ton of NO_X removed (Appendix 5) and is therefore an economically infeasible option.

The Department analyzed actual Continuous Emission Monitoring System (CEMS) data for NO_X emissions for existing municipal waste combustors in Pennsylvania. Based on these results (Appendix 6) and cost-effectiveness analysis, the Department is proposing that the owner and operator of a municipal waste combustor subject to § 129.111 shall comply with the presumptive RACT emission limitation of 150 ppmvd NO_X corrected at 7% oxygen. [25 Pa. Code § 129.112(f)]

(F) Combustion units or Process Heaters:

Natural gas-fired, propane-fired or liquid petroleum gas-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour:

Most natural gas-fired, propane-fired or liquid petroleum gas-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour units are equipped with LNB. The Department analyzed the actual stack test data for NO_X emissions that show as high as 0.99 lb NO_X/million Btu heat input. The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $8,905 - $18,334 per ton of NO_X removed (Appendix 7) and hence found SCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a natural gas-fired, propane-fired or liquid petroleum gas-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.10 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(i)]

Distillate oil-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour:

Most oil-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour units are equipped with LNB. The Department analyzed the actual stack test data for NO_X emissions that show as high as 0.11 lb NO_X/million Btu heat input. The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $6,719 - $13,899 per ton of NO_X removed (Appendix 8) and found SCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a distillate oil-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.12 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(ii)]

Residual oil-fired or other liquid fuel-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour:

Most residual oil-fired or other liquid fuel-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour units are equipped with LNB. The Department analyzed the actual stack test data for NO_X emissions that show as high as 0.37 lb NO_X/million Btu heat input. The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $4,400 - $8,552 per ton of NO_X removed (Appendix 9) and found SCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a residual oil-fired or other liquid fuel-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.20 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(iii)]

Refinery gas-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour:

Most residual oil-fired or other liquid fuel-fired combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour units are equipped with LNB. The Department analyzed the actual stack test data for NO_X emissions that show as high as 0.27 lb NO_X/million Btu heat input. The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $3,730 - $7,387 per ton of NO_X removed (Appendix 10) and found SCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a refinery gas-fired combustion unit or process heater, with a rated heat input equal to or greater than 50 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.25 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(iv)]

Coal-fired combustion unit with a rated heat input equal to or greater than 50 million Btu/hour and less than 250 million Btu/hour:

The Department has found only one unit in this category at a major NO_X emitting facility, which is a spreader stoker boiler. The Department analyzed the actual stack test data for NO_X emissions show as high as 0.36 lb NO_X/million Btu heat input. Most of the previous units were equipped with LNB. Test results for these coal-fired boilers show as high as 0.51 lb NO_X/million Btu heat input.

The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $4,338 - $8,247 per ton of NO_X removed (Appendix 11) and found SCR technology to be cost-prohibitive. The Department also evaluated SNCR cost-effectiveness ranging from $5,409 - $11,273 per ton of NO_X removed (Appendix 12) and found SNCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a coal-fired combustion unit with a rated heat input equal to or greater than 50 million Btu/hour and less than 250 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.45 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(v)]

Circulating fluidized bed primarily Bituminous waste (Gob)-fired or Anthracite waste (Culm)-fired combustion unit with a rated heat input equal to or greater than 250 million Btu/hour:

The Department analyzed CEMS NOx emissions data for three years (2018-2020) for Bituminous waste (Gob)-fired CFBs using EPA's Clean Air Market Division (CAMD) which showed there is no consistency in NOx emissions among units whether or not equipped with SNCR. These units are capable of achieving a NOx emission rate as low as 0.16 lbs/MMBtu with adequate margin to include variability in waste.

The Department evaluated cost-effectiveness for SNCR for CFB units with baseline emission rate of 0.16 lb NO_X/million Btu heat input that range from $4,747 - $6,207 per ton of NO_X removed (Appendix 13), which determined to be economically infeasible option.

Selective catalytic reduction has been demonstrated to achieve high levels of NO_X reduction on several types of combustion sources, including pulverized coal and stoker-type coal-fired boilers, but has not been demonstrated on CFB boilers. This technology could potentially be transferred to a CFB boiler, but not without significant difficulty: SCR installation upstream of the baghouse is technically infeasible because the particulate matter loading upstream of the baghouse will contain a very high loading of alkaline particulate matter that would likely preclude effective SCR operation, and SCR installation downstream of the baghouse is technically infeasible because the exhaust gas temperature at that location is too low to support effective SCR operation. This would require an additional burner that would reduce the unit efficiency for generating electricity and also emit additional air pollutants.

The Department also evaluated cost-effectiveness for SCR for CFB units with baseline emission rate of 0.16 lb NO_X/million Btu heat input that range from $5,507 - $9,060 per ton of NO_X removed (Appendix 14), which determined to be economically infeasible option. These costs-effectiveness do not include additional costs for a burner that would require to heat the exhaust gas post bag house.

Therefore, the Department is proposing that the owner and operator of a Circulating fluidized bed primarily Bituminous waste (Gob)-fired or Anthracite waste (Culm)-fired combustion unit with a rated heat input equal to or greater than 250 million Btu/hour shall comply with the existing presumptive RACT emission limitation of 0.16 lb NO_X/million Btu heat input on daily average. [25 Pa. Code § 129.112(g)(1)(vi)]

The Department also analyzed CEMS NOx emissions data for three years (2018-2020) for Culm-fired CFBs using EPA's Clean Air Market Division (CAMD) that ranges from 0.1 – 0.15 lb/MMBtu. The Department will solicit comments as to whether a separate Presumptive NOx emission limit for Anthracite waste (Culm)-fired CFBs be included in the final rule.

A solid fuel-fired combustion unit that is not a coal-fired combustion unit with a rated heat input equal to or greater than 50 million Btu/hour:

The Department analyzed test results for existing solid fuel-fired combustion units that are not coal-fired combustion units with a rated heat input equal to or greater than 50 million Btu/hour. The test results analyzed show these units are complying with the existing NO_X limit of 0.25 lb NO_X/million Btu heat input.

The Department evaluated SCR cost-effectiveness for various sizes of boilers that range from $7,562 - $13,971 per ton of NO_X removed (Appendix 15) and found SCR technology to be cost-prohibitive. The Department evaluated SNCR cost-effectiveness for various sizes of boilers that range from $7,840 - $18,200 per ton of NO_X removed (Appendix 16) and determined SNCR technology to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of solid fuel-fired combustion unit that is not a coal-fired combustion unit with a rated heat input equal to or greater than 50 million Btu/hour shall continue to comply with the existing presumptive RACT emission limitation of 0.25 lb NO_X/million Btu heat input. [25 Pa. Code § 129.112(g)(1)(vii)]

Circulating fluidized bed coal-fired combustion unit with a selective non-catalytic reduction system:

The Department is proposing that the owner or operator of a circulating fluidized bed coal-fired combustion unit shall control the NO_X emissions each operating day by operating the installed air pollution control technology and combustion controls at all times consistent with the technological limitations, manufacturer specifications, good engineering and maintenance practices, and good air pollution control practices for controlling emissions. [25 Pa. Code § 129.112(g)(1)(viii)]

Presumptive VOC RACT requirements for a combustion unit or combustion source with a rated heat input equal to or greater than 50 million Btu/hour, brick kiln, cement kiln, lime kiln:

The typical VOC emission range from natural gas-fired, distillate oil-fired, residual oil-fired or other liquid fuel-fired, refinery gas-fired, coal-fired or solid fuel-fired combustion unit that is not a coal-fired combustion unit, combustion unit or process heater with a rated heat input equal to or greater than 50 million Btu/hour range from 0.002 to 0.05 lb NO_X/million Btu heat input. The Department evaluated oxidation catalyst technology for VOC emission control from these sources using an average uncontrolled VOC emission rate of 0.01 lb VOC/million Btu heat input with 60% VOC control efficiency. The cost-effectiveness ranged from $46,853 to $96,929 per ton of VOC removed (Appendix 17). Therefore, the Department determined oxidation catalyst technology to be an economical infeasible option as RACT.

The Department is proposing that presumptive VOC RACT for a combustion unit or combustion source with a rated heat input equal to or greater than 50 million Btu/hour, brick kiln, cement kiln, or lime kiln shall continue to comply with the existing presumptive RACT emission requirements of installation, maintenance and operation in accordance with the manufacturer’s specifications and with good operating practices. [25 Pa. Code §129.112(d)]

(G) Combustion Turbines:

Natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 180 megawatts (MW):

Most of the turbines in this category are installed with DLNC.

The Department performed cost analysis for SCR for turbines between 1,000 and 60,000 bhp that range from $8,524 - $31,928 per ton of NO_X removed (Appendix 18). Because of its higher cost-effectiveness, SCR is determined to be a cost-prohibitive option.

The Department analyzed test results that included NO_X emissions as high as 40 ppm.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 180 MW shall continue to comply with the existing presumptive RACT emission limitation of 42 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(i)(A)]

The Department evaluated oxidation catalyst technology for VOC control for turbines between 6,000 and 60,000 bhp. The cost-effectiveness ranged from $13,201 to $137,719 per ton of VOC removed (Appendix 19). Therefore, the Department found oxidation catalyst an economical infeasible option as RACT.

The Department also analyzed actual VOC emissions data and based on the test results, and found that existing natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp are able to meet 5 ppm VOC or less (as propane) corrected at 15% oxygen.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 180 MW shall continue to comply with the existing presumptive RACT emission limitation of 5 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(i)(B)]

Fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 180 MW:

Based on the Department's record, there are no simple cycle or regenerative cycle combustion turbines with a rated output equal to or greater than 1,000 bhp and less than 180 MW and powered solely by fuel oil in the Commonwealth. There are turbines of this type that use oil as a start-up fuel before switching to natural gas. The existing requirements for these turbines are consistent with the requirement in the NSPS Part 60 Subpart KKKK.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 180 MW shall continue to comply with the existing presumptive RACT emission limitation of 96 ppmvd NO_X corrected at 15% oxygen [25 Pa. Code § 129.112(g)(2)(i)(C)] and existing presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(i)(D)]

Natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW:

All natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW are equipped with DLNC and SCR. The Department analyzed NO_X emissions test results for natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW. The test results show these turbines are able to achieve 4 ppmvd NO_X corrected at 15% oxygen.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW, shall continue to comply with the existing presumptive RACT emission limitation of 4 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(ii)(A)]

The Department analyzed test results for VOC emissions for natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbines with a rated output equal to or greater than 180 MW that show as high as 2 ppmvd VOC (as propane) corrected at 15% oxygen.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired combined cycle or combined heat and power combustion turbine, with a rated output equal to or greater than 180 MW shall continue to comply with the existing presumptive RACT emission limitation of 2 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(ii)(B)]

Fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW:

The existing NO_X RACT limit of 8 ppmvd corrected at 15% oxygen for fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW is consistent with fuel oil emission limits for a turbine equipped with SCR.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW, shall continue to comply with the existing presumptive RACT emission limitation of 8 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(ii)(C)]

The Department analyzed test results for VOC emissions for fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW that show as high as 2 ppmvd VOC (as propane) corrected at 15% oxygen.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired combined cycle or combined heat and power combustion turbine with a rated output equal to or greater than 180 MW, shall continue to comply with the existing presumptive RACT emission limitation of 2 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(ii)(D)]

Natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp:

The Department performed cost analysis for SCR for turbines between 1,000 and 3,000 bhp with existing RACT II emission rate of 150 ppmvd NO_X corrected at 15% oxygen that range from $21,206 - $27,748 per ton of NO_X removed (Appendix 20). Therefore, SCR is determined to be a cost-prohibitive option.

Most natural gas or noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbines with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp are installed with DLNC, and analysis of test results of actual NO_X emissions show as high as 84 ppmvd corrected at 15% oxygen. The Department also performed cost analysis for SCR for turbines between 1,000 and 3,000 bhp with NO_X emission rate of 85 ppmvd NO_X corrected at 15% oxygen and determined it to be a cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp, shall comply with the presumptive RACT emission limitation of 85 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iii)(A)]

The Department analyzed test results for VOC emissions for natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbines with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp that show as high as 9 ppmvd VOC (as propane) corrected at 15% oxygen.

The Department evaluated oxidation catalyst technology for VOC control with uncontrolled VOC emission rate of 9 ppmvd (as propane) corrected at 15% oxygen. The cost-effectiveness ranged from $68,488 to $76,026 per ton of VOC removed (Appendix 21). The Department determined oxidation catalyst technology to be economically cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp shall continue to comply with the existing presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iii)(B)]

Fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp:

Based on the Department's record, there are no simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 1,000 bhp and less than 3,000 bhp and powered solely by fuel oil in the Commonwealth. There are turbines of this type that use oil as a start-up fuel before switching to natural gas.

The Department performed cost analysis for SCR for turbines between 1,000 and 3,000 bhp with NO_X emission rate of 150 ppmvd NO_X corrected at 15% oxygen that range from $21,206 - $27,748 per ton of NO_X removed (Appendix 20). Therefore, SCR is determined to be a cost-prohibitive option.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp shall continue to comply with the existing presumptive RACT emission limitation of 150 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iii)(C)].

The Department evaluated oxidation catalyst technology for VOC control with uncontrolled VOC emission rate of 9 ppmvd (as propane) corrected at 15% oxygen. The cost-effectiveness ranged from $68,488 to $76,026 per ton of VOC removed (Appendix 21). The Department determined oxidation catalyst technology to be economically cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to or greater than 1,000 bhp and less than 3,000 bhp shall continue to comply with the existing presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iii)(D)]

Natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp:

All turbines in this category are installed with DLNC. The Department analyzed NO_X emissions test results for thirteen natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbines with a rated output equal to greater than 3,000 bhp and less than 6,000 bhp and found ten of them are able to achieve NO_X emission rate of 42 ppmvd corrected at 15% oxygen. Natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 6,000 bhp currently are required to meet with RACT II NO_X emission limit of 42 ppmvd corrected at 15% oxygen.

The Department evaluated cost analysis for SCR for turbines in this category with uncontrolled NO_X emission rate of 42 ppmvd corrected at 15% oxygen that range from $8,524 – 24,195 per ton of NO_X removed (Appendix 22) and determined SCR to be a cost-prohibitive option.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp shall comply with the presumptive RACT emission limitation of 42 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iv)(A)]

Most of the turbines in this size category meet 9 ppmvd VOC (as propane) corrected at 15% oxygen. As shown in Appendix 20, add on control such as oxidation catalyst is cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp shall comply with the presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iv)(B)]

Fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp:

Based on the Department's record, there are no fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp and powered solely by fuel oil in the Commonwealth. There are turbines of this type that use oil as a start-up fuel before switching to natural gas.

The Department performed cost analysis for SCR for turbines between 3,000 and 60,000 fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp and RACT II limit of 96 ppmvd NO_X corrected at 15% oxygen that range from $7,813 – $21,859 per ton of NO_X removed (Appendix 23). Therefore, SCR is determined to be a cost-prohibitive option.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp shall continue to comply with the existing presumptive RACT emission limitation of 96 ppmvd NO_X corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iv)(C)]

Also, as shown in Appendix 20, add-on control such as oxidation catalyst is cost-prohibitive for the turbine with the existing presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen.

Therefore, the Department is proposing that the owner and operator of a fuel oil-fired simple cycle or regenerative cycle combustion turbine with a rated output equal to greater than 3,000 bhp and less than 60,000 bhp shall continue to comply with the existing presumptive RACT emission limitation of 9 ppmvd VOC (as propane) corrected at 15% oxygen. [25 Pa. Code § 129.112(g)(2)(iv)(D)]

(H) Stationary Internal Combustion Engines:

Natural gas or a noncommercial gaseous fuel-fired lean burn stationary internal combustion engine with a rating equal to or greater than 500 bhp and less than 3,500 bhp:

Most of these engines are equipped with LEC technology. Test results for natural gas engines above 500 bhp show NO_X emissions as high as 3.0 gram NO_X/bhp-hr. Engines manufactured on or after July 1, 2007, and subject to 40 CFR Part 60 Subpart JJJJ, are required to meet the emission limitation of 2 gram NO_X/bhp-hr; and, engines manufactured on or after July 1, 2010, are required to meet the emission limitation of 1 gram NO_X/bhp-hr. The Department performed cost analysis for SCR for engines rated between 500 and 3,500 bhp that range from $3,871 to $10,449 per ton of NO_X removed (Appendix 24) and determined SCR technology as a cost-prohibitive option.

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired lean burn stationary internal combustion engine with a rating equal to or greater than 500 bhp and less than 3,500 bhp shall continue to comply with the existing presumptive RACT emission limitation of 3.0 gram NO_X/bhp-hr. [25 Pa. Code § 129.112(g)(3)(i)(A)]

Natural gas or a noncommercial gaseous fuel-fired lean burn stationary internal combustion engine with a rating equal to or greater than 3,500 bhp

Most of these engines are equipped with LEC technology with 3.0 gram NO_X/bhp-hr limit. The Department performed cost analysis for SCR with 80% NO_X reduction efficiency for engines rated at greater than 3,500 bhp that range from $3,326 - $3,676 for ton of NO_X removed. (Appendix 25).

Therefore, the Department is proposing that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired lean burn stationary internal combustion engine with a rating equal to or greater 3,500 bhp shall comply with the presumptive RACT emission limitation of 0.6 grams NO_X/bhp-hr. [25 Pa. Code § 129.112(g)(3)(ii)(A)]

Liquid fuel or dual-fuel-fired stationary internal combustion engine with a rating equal to or greater than 500 bhp

The Department performed cost analysis for SCR with 80% is cost-effective for diesel engines between 500 to 5,000 bhp with existing RACT II limit of 8 gm NO_X/bhp-hr and found the cost range from $2,543 - $3,503 (Appendix 26).

Therefore, the Department is proposing that the owner and operator of a liquid fuel or dual-fuel-fired stationary internal combustion engine with a rating equal to or greater than 500 bhp shall comply with the presumptive RACT emission limitation of 1.6 gram NO_X/bhp-hr. [25 Pa. Code § 129.112(g)(3)(iii)]

Natural gas or a noncommercial gaseous fuel-fired rich burn stationary internal combustion engine with a rating equal to or greater than 100 bhp:

Typical uncontrolled NO_X from natural gas-fired rich-burn engines range from 13 - 16 gram NO_X/bhp-hr. During RACT II development, the Department determined that NSCR with 80% NO_X removal efficiency is technically and economically feasible and established NO_X emission rate of 2.0 gram NOx/bhp-hr for rich-burn engines rated at equal to or greater than 500 bhp.

Most of the rich-burn engines greater than 500 bhp are retrofitted with NSCR or equivalent technology that reduces NO_X emission at 2 gram NO_X/bhp-hr or less. The Department further evaluated economic feasibility for NSCR technology for engines rated at as low as 100 bhp. NO_X efficiency for NSCR technology varies from 80 – 95% depending on the small to large size engines. The cost analysis was performed with an average 80% NO_X and 50% VOC reduction efficiency that range from $70 - $616 for ton of NO_X and VOC removed (Appendix 27).

Therefore, the Department has expanded the applicability range to engines as small as 100 bhp and proposed that the owner and operator of a natural gas or a noncommercial gaseous fuel-fired rich burn stationary internal combustion engine with a rating equal to or greater than 100 bhp shall comply with the presumptive RACT emission limitation of 2.0 gram NO_X/bhp-hr [25 Pa. Code § 129.112(g)(3)(iv)(A)] and presumptive RACT emission limitation of 0.5 gram VOC/bhp-hr. [25 Pa. Code § 129.112(g)(3)(iv)(B)]

Presumptive VOC RACT requirements for all internal combustion engines:

The Department evaluated cost-effectiveness for oxidation catalyst technology for all internal combustion engines rated at equal to or greater than 500 bhp with existing limit of 1.0 gram VOC/bhp-hr and found to be between approximately $2,000 to $4,000 per ton of VOC removed (Appendix 28) and therefore determined to be an economically feasible option.

The Department further reviewed the stack test results for sample of internal combustion engines and found the VOC emission as high as 0.5 gram VOC/bhp-hr.

Therefore, the Department determined the presumptive VOC RACT for all lean-burn internal combustion engines rated at equal to greater than 500 bhp at 0.5 gram VOC/bhp-hr. excluding formaldehyde. [25 Pa. Code § 129.112(g)(3)(i)(B)] and [25 Pa. Code § 129.112(g)(3)(ii)(B)]

(I) Portland Cement Kilns:

EPA has evaluated SCR systems for use at cement kilns and has found that they are technically feasible. As per summary of comments received regarding Consent Decree between Lehigh Cement and EPA dated March 27, 2020, at many cement kilns, installation and operation of SCR is cost prohibitive and would increase the cost per ton of clinker to such an extent that it may render the cement plant economically non-viable. Therefore, the Department believes that SCR technology for cement kilns are economically infeasible option.

Long wet-process cement kiln:

All long wet-process cement kilns in Pennsylvania are installed and operating with SNCR. The Department evaluated NO_X test results for a long-wet process cement kiln located at Armstrong Cement.

Based on the test results, the Department is proposing that the owner and operator of a long wet-process cement kiln shall continue to comply with the existing presumptive RACT emission limitation of 3.88 pounds of NO_X per ton of clinker produced. [25 Pa. Code § 129.112(h)(1)]

Long dry-process cement kiln:

All long dry-process cement kilns in Pennsylvania are installed and operating with SNCR. The Department evaluated NO_X test results for a long-wet process cement kiln located at Evansville Cement.

Per a consent decree between EPA and Lehigh Cement Evansville, a limit of 3.0 pounds of NO_X per ton of clinker produced is established.

Therefore, the Department is proposing that the owner and operator of a long dry-process cement kiln shall comply with the presumptive RACT emission limitation of 3.0 pounds of NO_X per ton of clinker produced. [25 Pa. Code § 129.112(h)(2)]

Preheater and Precalciner cement kiln:

Precalciner cement kilns are equipped with SNCR. SCR systems applied to cement preheater/precalciner (PH/PC) kilns can be either "low-dust" or "high-dust" systems depending on their location after or before the particulate matter control device. In both types of systems, capital costs include the cost of the SCR catalyst and reactor, the costs to upgrade or replace kiln ID fans when SCR is added to existing PH/PC kilns, and the costs of the reagent delivery system, storage, and instrumentation. Because of the problems of catalyst plugging, the high-dust system requires a catalyst cleaning mechanism, such as pressurized air nozzles or sonic horns. The low-dust system avoids costs associated with catalyst cleaning. Operating costs include operating labor and maintenance costs, reagent costs, and the electricity of reagent pumping. High-dust SCR systems incur higher energy costs for catalyst cleaning. Operating cost also include catalyst replacement every few years.

As per EPA's "Alternative Control Techniques Document Update - NO_X Emissions from New Cement Kilns" (EPA-453/R-07-006 November 2007) document, the average cost-effectiveness of SCR for PH/PC kilns are approximately $4,200 per ton of NO_X removed. Therefore, the Department has determined SCR to be a cost-prohibitive option for PH/PC cement kilns.

As per the consent decree, Lehigh Cement kiln at Nazareth's is limited to 2.30 pounds of NO_X per ton of clinker produced.

Therefore, the Department is proposing that the owner and operator of a Preheater and Precalciner cement kiln shall comply with the presumptive RACT emission limitation of 2.30 pounds of NO_X per ton of clinker produced. [25 Pa. Code § 129.112(h)(3)]

VOC RACT for all cement kilns:

Based on the cost analysis performed for CO Catalyst for combustion units and combustion sources, add-on control such as oxidation catalyst is cost-prohibitive for combustion units or sources located at all cement plants (Appendix 16). Therefore, the Department is proposing that an owner or operator of a cement kiln shall continue to comply with the existing presumptive VOC RACT requirements of installation, maintenance, and operation of the source in accordance with manufacturer's specifications and with good operating practices.

(J) Glass Melting Furnaces:

There are several glass melting furnaces in Pennsylvania that are major source emitters of NO_X. Most of the glass furnaces in Pennsylvania are equipped with SCR, LNB or Oxy-Firing and Air Staging controls.

Several alternative control technologies are available to glass manufacturing facilities to limit NO_X emissions. These options include combustion modifications (low NO_X burners, oxy-fuel firing, oxygen-enriched air staging), process modifications (fuel switching, batch preheat, electric boost), and post combustion modifications (fuel reburn, SNCR, SCR). Oxy-firing is effective NO_X emission reduction technique and is best implemented with a complete furnace rebuild. This strategy not only reduces NO_X emissions by as much as 85 percent, but reduces energy consumption, increases production rates by 10 to 15 percent, and improves glass quality by reducing defects. Oxy-firing is demonstrated technology and has penetrated all segments of the glass industry.

The Department performed cost analysis for SCR for those glass furnaces that are equipped with LNB or Oxy-Firing controls.

Container glass furnace:

All existing container glass furnaces are equipped with Oxy-firing and LNB. The Department performed cost analysis for SCR that range from $4,356 - $5,064 per ton of NO_X removed (Appendix 29) and determined to be cost-prohibitive.

Therefore, the Department is proposing that the owner and operator of a container glass furnace shall comply with the presumptive RACT emission limitation of 4.0 pounds of NO_X per ton of glass pulled, which is consistent with the recommended emission limit in OTC's (Ozone Transport Commission) "Identification and Evaluation of Candidate Control Measures Final Technical Support Document" and 25 Pa. Code §129.304. [25 Pa. Code § 129.112(i)(1)]

Pressed or Blown glass furnace:

All existing pressed or blown glass furnaces are equipped with SCR.

Therefore, the Department is proposing that the owner and operator of a pressed or blown glass furnace shall comply with the presumptive RACT emission limitation of 7.0 pounds of NO_X per ton of glass pulled, which is consistent with the recommended emission limit in OTC's "Identification and Evaluation of Candidate Control Measures Final Technical Support Document" and with 25 Pa. Code §129.304. [25 Pa. Code § 129.112(i)(2)]

Fiberglass furnace:

No fiberglass furnace is found in Pennsylvania subject to RACT. For any fiberglass furnace in Pennsylvania that becomes subject to RACT, the Department is proposing NO_X RACT limit for fiberglass furnace at 4.0 pounds of NOX per ton of glass pulled. [25 Pa. Code § 129.112(i)(3)].

This emission limit is also consistent with recommended emission limit in OTC's "Identification and Evaluation of Candidate Control Measures Final Technical Support Document" and 25 Pa. Code §129.304.

Flat glass furnace:

Most flat glass furnaces in Pennsylvania are equipped with Oxy-firing and LNB or SCR with controlled emission rate of 7 lbs/ton of glass pulled. However, one glass furnace in Pennsylvania is operating with a NOx limit of 26.75 lb/ton of glass pulled. This glass furnace is not able to meet proposed RACT III NOx limit of 7 lbs/ton of glass pulled herefore. The Department evaluated a cost-analysis for SCR for flat glass furnace and found it to be less than $1,000 approximately removed.

Since most flat glass furnaces are equipped with Oxy-firing and LNB or SCR, the Department is proposing that the owner and operator of a flat glass furnace shall comply with the presumptive RACT emission limitation of 7.0 pounds of NO_X per ton of glass pulled, which is consistent with the recommended emission limit in OTC's "Identification and Evaluation of Candidate Control Measures Final Technical Support Document" and 25 Pa. Code § 129.304. [25 Pa. Code § 129.112(i)(4)]

All other glass melting furnaces:

All other glass furnaces are equipped with LNB or Air Staging controls. The Department performed incremental cost analysis for SCR and found to be higher than $3,950 per ton of NO_X removed and determined to be cost-prohibitive (Appendix 30).

The Department evaluated a test result for NO_X emissions for other glass melting furnace that shows NO_X emissions as high as 5.7 pounds of NO_X per ton of glass pulled. Therefore, the Department is proposing that the owner and operator of any other type of glass melting furnace shall comply with the presumptive RACT emission limitation of 6.0 pounds of NO_X per ton of glass pulled on a 30-days rolling average basis that is consistent with 25 Pa. Code § 129.304. [25 Pa. Code § 129.112(i)(5)]

(K) Lime Kilns:

The Department evaluated SCR technology for long rotary kiln. U.S. EPA's (SCR) RACT/BACT/LAER Clearinghouse (RBLC) does not show this technology as being applied to either long rotary or preheater lime kiln. SCR is generally not considered technically feasible option for long rotary lime kiln because of particulate fouling, especially with calcium-based particulates. Optimum temperature for SCR is significantly higher than the exhaust gas temperatures from long rotary kiln (typically less than 500 deg. F) and exhaust gas temperature fluctuation and variability in long rotary kiln hinders control efficiency of SCR. Therefore, the Department has determined SCR to be a technically infeasible option.

SNCR technology has not been applied to a long rotary lime kiln where the reagent must be injected into the calcining zone of the kiln. The location of the injection point is critical to the level of reduction of NO_X. The optimal location of the injection point in a long rotary kiln is variable and the ability to match injection location to the NO_X concentration is difficult and inaccurate. Failure to match the required criteria could result in poor effectiveness and/or by-product generation of NO_X from the ammonia reagent. Application of the technology at a long rotary kiln has not been installed and currently not a reasonable control alternative. Therefore, the Department has determined SNCR technology to be a technically infeasible option.

Combustion/burner optimization techniques such as Low Excess Air, Overfire Air, Low NO_X Burner and Flue Gas Recirculation can reduce NO_X emissions by 5 to 60 percent. The goal of these control techniques is to optimize the efficiency of combustion while minimizing emissions of NO_X. The Department reviewed the operating permit for a long rotary lime kiln No. 5 at Carmeuse Lime, Inc. The kiln incorporates combustion controls using multi-channel, multi-fuel feed burners. Carmeuse has an on-going program designed to minimize NO_X emissions through combustion of various fuels. Where applicable, depending on fuel type, product mix, and process conditions, the program incorporates an appropriate combustion/burner optimization technique. During the RACT II evaluation, the Department revised the NO_X emission limit from 6 to 4.6 lb of NO_X per hour with combustion/burner optimization for Kiln No. 5 at Carmeuse Lime, Inc.

Therefore, the Department is proposing that the owner and operator of all lime kiln shall comply with the presumptive RACT emission limitation of 4.6 lb of NO_X per hour. [25 Pa. Code § 129.112(j)]

Direct-fired Heater, Furnace or Oven with a rated heat input equal to or greater than 20 million Btu/hour:

The Department has found that all direct-fired heaters, furnaces or ovens are natural gas-fired and should be able to achieve NO_X emission rate similar to natural gas, propane or LPG-fired combustion units or process heaters.

Therefore, the Department is proposing that the owner and operator of a direct-fired heater, furnace or oven with a rated heat input equal to or greater than 20 million Btu/hour shall comply with the presumptive RACT emission limitation of 0.10 lb. NO_X/million Btu heat input on a daily average basis or as determined based on actual stack test results. [25 Pa. Code §129.112(k)]

(L) Alternative RACT proposals:

Owners and operators of sources that cannot meet presumptive RACT requirements or emission limitations may elect to meet the applicable NO_X RACT emission limitation by averaging NO_X emissions on either a facility-wide or system-wide basis. [25 Pa. Code § 129.113(a)]

Owners and operators of sources that cannot meet presumptive RACT requirements or emission limitations or by averaging NO_X emissions on either a facility-wide or system-wide basis will be required to evaluate RACT requirements on a case-by-case basis for NO_X and/or VOCs. [25 Pa. Code § 129.114(a)]

Owners and operators of sources that are subject to the RACT III regulation but do not have presumptive RACT requirements for the sources must evaluate RACT requirements on a case-by-case for NO_X and VOCs as applicable.

Case-by-case RACT proposals must be submitted to appropriate regional offices by *****, ** 202*. [25 Pa. Code § 129.114(d)(1)

The owner or operator must complete the implementation of the case-by-case RACT by *****, ** 202*. [25 Pa. Code § 129.114(d)(4)

If an owner or operator is going to install a control device as part of case-by-case RACT, the owner or operator may petition the department for an alternate compliance schedule. [25 Pa. Code § 129.114(j)]

The procedure is identical to the alternate compliance schedule procedure for presumptive RACT, including interim RACT emission limitations.

The owner or operator must complete the implementation of the case-by-case RACT by ** **, 20**. [25 Pa. Code § 129.114(j)(2)(v)

If an owner or operator proposes to permanently remove a subject source from operation, the final compliance date will be determined on a case-by-case basis and may be longer than 3 years from petition approval

The case-by-case RACT proposal shall be submitted in accordance with procedures in the case-by-case RACT requirements in [25 Pa. Code § 129.114(d)]

The proposal must also include testing, monitoring, recordkeeping, and reporting requirements to show compliance with the proposed case-by-case RACT.

(M) Compliance Demonstration:

An owner or operator must demonstrate compliance with the RACT III regulation by *****, **, 202*. An owner or operator subject to RACT III has two compliance options.

Compliance with presumptive RACT requirements and/or emission limitations.

Case-by-case RACT determinations.

The owner or operator of a source with CEMS shall show compliance with the presumptive RACT emission limitations on 30-day rolling average basis, as required. [25 Pa. Code § 129.115(b)(1)]

The clinker production rate for Portland cement kilns is calculated in accordance with 40 CFR Part 63, Subpart LLL § 63.1350(d). [25 Pa. Code § 129.115(b)(2)]

Compliance with the presumptive NO_X RACT emission limitation for municipal waste combustors with CEMS shall be shown as a daily rolling average, calculated in the same manner as currently applied to CEMS. [25 Pa. Code § 129.115(b)(3)]

The owner or operator of a source without CEMS shall show compliance with the presumptive RACT emission limitations with a department-approved emissions source test that meets the requirements of Chapter 139. The testing shall be conducted at least once in each 5-year calendar period. [25 Pa. Code § 129.115(b)(5)]

(N) Recordkeeping and Reporting:

The owner or operator of a source is required to all applicable recordkeeping and reporting requirements as established in 25 Pa. Code § 129.115.

APPENDIX 1

GUIDANCE DOCUMENT ON REASONABLY AVAILABLE CONTROL TECHNOLOGY FOR SOURCES OF NOx EMISSIONS

2/01/94

INTRODUCTION:

Pennsylvania's regulation, Title 25, Environmental Resources, Article III, Chapter 129, Standards for Sources, Section 129.91, requires Reasonably Available Control Technology (RACT) to be determined on a case-by-case basis for major sources or facilities. RACT is defined as: The lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility.

Presumptive RACT standards have been established in Section 129.93 for certain select source categories. In many states, presumptive standards are the norm with emission limitations or technologies established for most major categories. However, because Pennsylvania has more sources with a greater degree of diversity, the case-by-case RACT process is preferred.

This document is therefore intended to provide guidance and information needed to examine the case-by-case RACT determinations for the affected sources or facilities. In cases where the regulations have provided presumptive RACT, further details on the rationale for the presumptive standards will be given.

Section I contains a general discussion of the Clean Air Act Amendments (CAAA) and how it affects the Commonwealth. A discussion on the NOx emission inventory is included. Section II describes the RACT submittal process and the subsequent case-by-case NOx RACT determination procedures. Section III contains the criteria for allowing emission averaging. Section IV includes the guidance on the establishment of final RACT limitations using actual emission data.

Attachment 1 provides a general summary of various NOx control strategies, followed by a series of Modules which describe in detail the application of NOx RACT for various source categories. The modules are compilation of available information on these source categories. Depending upon the need, specific Modules may be requested by the interested parties. The Modules available are as follows:

Module 1- Utility Boilers and Boilers >= 100 MMBtu/hr
Module 2- Industrial, Commercial, Institutional boilers <100 MMBtu/hr
Module 3- Internal Combustion Engines
Module 4- Turbines
Module 5- Glass Furnaces
Module 6- Process Heaters
Module 7- Iron and Steel Mills
Module 8- Cement Manufacturing
Module 9- Miscellaneous and Presumptive RACT Sources

APPENDIX 1

I. GENERAL DISCUSSION:

The Clean Air Act Amendments (CAAA) of 1990 require Pennsylvania to meet the health-related, ground level ozone National Ambient Air Quality Standard (NAAQS). In the presence of sunlight, oxides of nitrogen (NOx), and volatile organic compounds (VOC) react to form ground level ozone. Ozone is a known respiratory irritant, and may significantly reduce the yield of important food crops. Ozone may also cause degradation of paint, plastics, textiles and rubber. NOx is also a precursor to acid deposition. NOx, in the form of Nitrogen Dioxide, (NO_2) is known to aggravate symptoms associated with asthma and bronchitis. NO_2 can also increase susceptibility to respiratory infections. Ground level ozone should not be confused with stratospheric ozone which is beneficial and needed in the upper levels of the atmosphere to block harmful radiation from the sun.

Attaining the ozone air quality standard is a statewide problem for Pennsylvania. A number of counties are classified as nonattainment for not meeting the NAAQS. The CAAA created a special classification system of ozone nonattainment areas depending on the severity of the ozone levels within a consolidated metropolitan statistical area (CSMA). Figure 1 shows these classifications for Pennsylvania. Some counties are classified as nonattainment but are not part of a CMSA.

The five-county Pennsylvania portion of the Philadelphia CSMA is classified as a severe area. In fact, there are serious region-wide violations of the ozone standard throughout the entire northeastern United States. The CAAA address this problem of regional nonattainment through the establishment of the Ozone Transport Region (OTR), of which Pennsylvania has been designated as one of its 13 states or political entities. At a minimum, this action requires that any major VOC or NOx source in the entire state of Pennsylvania is subject to the requirements that apply to major sources in ozone areas classified as moderate, even though some Pennsylvania counties are achieving the NAAQS attainment levels. The major sources located in the Philadelphia Metropolitan Statistical Area are subject to the requirements of severe ozone nonattainment area.

The CAAA require areas which exceed NAAQS for ozone to implement NOx RACT programs for all major NOx facilities. The RACT programs are to apply to all facilities which emit or have the potential to emit greater than 100 tons per year of NOx. In the case of severe nonattainment areas such as the five-county Pennsylvania portion of Philadelphia CSMA facilities of greater than 25 tons per year of NOx are subject to RACT requirements.

Regarding the applicability, if the facility's "potential to emit" was above the RACT threshold (e.g 100 TPY) but the actual emissions for the year 1990 calendar year and for the subsequent years were below the threshold, the facility has the option to accept a federally enforceable condition to limit the emissions to be under the applicability

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threshold. Such a condition would make the facility "synthetic minor" and would not be subject RACT requirements. Since the Pennsylvania's operating permit is not currently federally enforceable, the permit amendment with such conditions must be incorporated in to Pa's SIP as revisions in order to make them federally enforceable.

On the other hand, if the facility's actual emissions for the calendar year 1990 were above the RACT applicability threshold, the facility could never be made "synthetic minor" even if the facility is willing to limit the emissions in the future. Thus such facility would be subject to the RACT.

NOx Emissions Distribution By Source

Statewide, mobile sources make up 31% of the total NOx emissions. The remaining 69% comes from stationary sources. Of the latter, the utility industry accounts for 80% of the total NOx emissions. Natural gas transmission accounts for 5% of the total stationary source NOx emissions while the remaining 15% of NOx is derived from miscellaneous sources. Of these miscellaneous sources, glass manufacturing accounts for slightly greater than 1% of the total NOx emissions and asphalt plants less than 1% of the total. Other industries include miscellaneous utilities at 1%, metallurgical at 3%, chemical industry at less than 1%, refining at 2%, mineral industry at 3%, and all other sources at 5%. (See Figure 2 and Table 1) This information was extracted from Pennsylvania Emission Data System (PEDS). Due to thresholds established for including in the PEDS, all the sources in some source categories such as asphalt plants were not included in the PEDS.

The proposed NOx RACT standards are mandated for the ozone non-attainment areas and are part of the strategy to bring Pennsylvania into attainment of the NAAQS for ozone. Due to the implementation of RACT we anticipate the NOx emissions from stationary sources to be reduced by about 35-40 percent.

Preliminary emissions modeling via ROMNET indicates that the first stage RACT reductions may not be sufficient to achieve NAAQS by the stipulated deadlines. Therefore, additional emission reductions may be necessary to achieve attainment of ozone standard in Pennsylvania.

Other states are in various stages of developing their NOx RACT. A summary of their regulations may be found in Table 2 at the end of this document.

II. GUIDANCE FOR SUBMITTING RACT PROPOSALS FOR MAJOR NOX SOURCES:

The final regulation does establish presumptive RACT requirements for three major classes of NOx emitters. For certain small combustion units and certain other classes of fossil fuel burning equipment, presumptive RACT is determined to be the operation of the sources in accordance with the manufacturer's specifications. For certain larger combustion units, RACT is specified to be an annual tune-up and combustion adjustments to provide for low-NOx emitting operation. For very large coal fired combustion units, presumptive RACT is specified to be a low-NOx burner system with separate overfire air.

Although presumptive RACT requirements are contained in the final regulation for certain NOx sources, a source operator may elect to use a case-by-case analysis to establish RACT requirements.

Facilities which are subject to RACT are required to identify themselves within four months of the date of publication of the final regulations in the Pennsylvania Bulletin. These facilities are required to submit a written proposal for RACT for each source to the Department and EPA within six months of adoption of the regulations. All affected facilities must be in compliance with the NOx RACT regulations by May 31, 1995. This deadline is mandated by the CAAA. Therefore, the owner or operator of a source or facility for which RACT is required must obtain approval for a RACT proposal and implement it by May 31, 1995.

Implementing the plan includes obtaining the required permits, installing the approved NOx control, implementing process changes, and complying with all emission limits established by the Department. An owner or operator seeking a RACT determination, and installing an air pollution control device must also submit an application for a Plan Approval, as specified in Chapter 127.

Because the date of RACT implementation is fixed and not dependent upon intermediate events or other regulation promulgation, some facilities may be tempted to initiate control/process changes in the name of RACT without proper permitting. These industries run the risk of wasting money and time on projects which will not pass the review process. Therefore, facilities should obtain approval prior to proceeding with the implementation of the plan.

The case-by-case RACT determinations will require EPA approval as SIP revisions. The Department will coordinate its review of RACT proposals with EPA. The Department will expedite the SIP hearing and submission to assure EPA action as early as possible. After EPA's approval of the RACT regulation, the RACT program which implements the presumptive RACT requirements will not require SIP approval. Sources meeting the presumptive levels contained in the regulation do not have to prepare an alternative analysis identifying and evaluating different control scenarios.

Presumptive RACT requirements for oil/gas fired combustion units

It was brought to the Department's attention that the language in the regulation (§ 129.93 (b) (4) could be interpreted as the only presumptive RACT requirement for oil, gas and combination oil/gas fired units irrespective of heat input is recordkeeping. As indicated in the

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background material provided to EQB, the Department's intent was for the oil/gas fired units with rated heat inputs greater than 50 million Btu per hour to be handled through the case-by-case process. The record keeping requirement was intended to be applicable to the oil/gas fired units with rated heat inputs equal to or greater than 20 million Btu per hour. The regulation should be read as follows:

§129.93 (b) (4) (Add the underlined language)
(4) For oil, gas and combination oil/gas units <u>subject to subsection (2),</u> the owner and operator shall maintain records including a certification from the fuel supplier of the type of fuel and for each shipment of distillate oils number 1 or 2, a certification that the fuel complies with ASTM D396-78 "Standard Specifications for Fuel Oils". For residual oils minimum recordkeeping includes a certification from the fuel supplier, of the nitrogen content of the fuel, and identification of the sampling method and sampling protocol.

The Department is planning to clarify the intent of Section 129.93 (b) (4) through an amendment to the regulation. **Content of RACT Proposal:**

The RACT proposal shall include at a minimum:

1) A list of each unit subject to the NOx RACT regulations;

2) The size or capacity of each affected unit and the types of fuel or fuels combusted in each unit;

3) A complete description of each source;

4) Estimated NOx emissions and associated support documents;

5) RACT analysis including technical and economic support documentation for each affected source;

6) A schedule for the implementation of RACT including provisions for demonstrating periodic increments of progress and compliance with RACT

7) The testing, monitoring, record keeping and reporting procedures to be used to demonstrate compliance with RACT.

8) Additional information requested by the Department that is deemed necessary for the determination of RACT.

Guidance for the Case-by-Case RACT analysis:

RACT is defined as the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility.

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The RACT analysis must include a ranking of all applicable and available control technologies for the affected source in descending order of control effectiveness. The applicant first examines the most stringent or "top" alternative. If it can be shown that this level of control is technically or economically infeasible for the source under review, then the next most stringent level of control is determined and similarly evaluated. The analysis continues until the RACT level under consideration cannot be eliminated by any substantial or unique technical or economic objection.

Step-by-step summary of the RACT analysis process:

STEP 1 : Identify all applicable control technologies

The first step is to identify for each affected source all applicable and available control options. Available control options are those air pollution control technologies or techniques with a practical potential for application to the source. Air pollution control technologies and techniques include the application of production process or methods, control systems, and the fuel combustion techniques for the control of NOx. The control technologies shall include not only existing controls for the source category, but also technology transfer controls applied to similar source categories.

STEP 2: Eliminate technically infeasible options

In the second step, the technical feasibility of the available control options identified in Step 1 is to be evaluated with respect to the source-specific factors. A demonstration of technical infeasibility should be clearly documented based on physical, or chemical and engineering principles, that technical difficulties would preclude the successful use of the control option on the affected source.

Technically infeasible control options are then eliminated from further consideration in the RACT analysis.

Availability of Technically Feasible options: If a technically feasible option cannot be implemented by May 31, 1995 due to temporary inability (for example, manufacturer's inability to supply the equipment on required schedule) such a option cannot be eliminated from RACT consideration. This issue will be dealt as an enforcement issue rather than a RACT determination issue.

STEP 3: Rank remaining control technologies by control effectiveness

In step 3, all remaining control options not eliminated in Step 2 are ranked and then listed in order of overall control effectiveness for the NOx emissions. The list should present the array of control options and should include as a minimum the following information:

1) Baseline (before RACT) emissions

2) control efficiencies

3) expected emissions after the application of the control option
4) economic impacts (both overall cost effectiveness and incremental cost effectiveness)

However, if the proposal selects the top control option the detailed cost analysis is not needed.

Cost-effectiveness:

Cost-effectiveness, in terms of dollars per ton of NOx emissions reduction, is the key criterion to be used in assessing the economic feasibility of a control option. In the economic impacts analysis, primary consideration should be given to quantifying the cost of control and <u>not the economic situation</u> of the affected facility. By expressing costs in terms of the amount of emission reduction achieved, comparisons can be more readily performed among the same type of sources for different facilities.

The cost-effectiveness calculations can be conducted on an average or incremental basis. Average cost-effectiveness is calculated as the annualized cost of the control option being considered divided by the baseline emissions minus the control option emission rate, as shown by the following formula:

Average cost effectiveness (\$/ton removed) =

$$\frac{\text{Control option annualized cost (\$/yr)}}{\text{Baseline emission rate - Control option rate (tons/yr)}}$$

The average cost-effectiveness is also referred to as overall or total cost effectiveness.

The baseline emissions rate represents the maximum emissions before the application of the RACT. It should be calculated using either continuous emission monitoring data (CEM), test results or approved emission factors and historic operating data.

The incremental cost effectiveness calculation compares the costs and emission level of a control option to those of the next most stringent option as shown in the following formula:

Incremental Cost (dollars per incremental ton removed) =

$$\frac{\text{Total cost (annualized) of control option - Total cost (annualized) of next option}}{\text{Next control option emission rate - control emission rate}}$$

Incremental cost-effectiveness comparisons should focus on annualized cost and mission reduction differences between dominant control options.

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The incremental cost-effectiveness should be examined in conjunction with the total cost effectiveness in order to justify elimination of a control option. The primary focus will be on the total cost effectiveness.

For the cost estimates to be used in the economic analysis the data supplied by an equipment vendor (i.e., budget estimates or bids) must be used as much as possible. The basis of the estimates must be thoroughly documented in the RACT analysis. The cost analysis must be consistent with OAQPS Control Cost Manual, (Fourth Edition), EPA 450/3-90-006, January 1990 or as revised.

STEP 4 : Selection of RACT

The Department will generally consider the control option to be cost effective if the total cost effectiveness is no greater than $1500 per ton of NOx reduced.

In addition to the average cost effectiveness of $1500/ton, other factors such as the incremental cost effectiveness and other environmental impacts will also be considered in the RACT determination. For example, a control option with average cost effectiveness less than $1500/ton would not be automatically considered as a RACT option if it causes significant adverse impact on the other media. The adverse side effects of each control option must be factored in the RACT determination process.

We should caution that US EPA Region III has stated that establishing **any** dollar figure in RACT guidance will not provide for an "automatic" selection or rejection of a control technology or emission limitation as RACT for a source or source category. We also understand that EPA headquarters is planning to finalize a guidance document on cost effectiveness for NOx RACT analysis. The document will suggest that a cost effectiveness of up to $2,500 is reasonable.

Rationale for selection of cost effectiveness criteria:

It should be noted that in Pennsylvania the number of affected sources and the types of sources are substantially greater than most of the states in Ozone Transport Region (OTR). Also, the baseline emissions of these sources vary widely. Thus, there is a need for a case-by-case RACT determination as opposed to one set of presumptive limits. While it is appropriate to establish site specific limits the degree of control must be comparable to the other states in OTR.

We applied the following criteria in establishing the cost-effectiveness level. First, the cost of control should be fair and equitable to all. Second, the acceptable control costs should be comparable to costs required to employ the presumptive technology requirements for the large coal fired boilers. Third, the cost effectiveness should be reasonable when compared to the acceptable costs

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established in the existing permitting or regulatory process such as the acceptable costs for BACT determination for new NOx sources and control cost for sources of volatile organic compounds (the other major ozone precursor) to comply with existing RACT regulations based on EPA's guidelines. Finally, the cost-effectiveness should be comparable to that established in other states in the OTR.

The presumptive RACT requirements included in our regulations for coal-fired combustion units with a rated heat input equal to or greater than 100 million Btus per hour, are the installation and operation of low-Nox burners with separated overfire air (LNB-SOFA). As per EPA document "Evaluation and Costing of NOx Controls for Existing Utility Boilers in the NESCAUM Region", the control costs for LNB-SOFA vary from $270 to $1,590 per ton of NOx removed depending on site specific factors (such as the type of boiler, size of the boiler and the amount of utilization). The control measures available to achieve the levels established as presumptive RACT for utility boilers by other states show a range of cost-effectiveness from about $570-$1500 per ton. In fact, two NOx RACT proposals using LNB-SOFA have documented cost of $1,222 and $1,298 per ton.

Therefore, we decided to apply an target limit of one level to all source categories and the level will be set at $1500 per ton.

The Department suggests using $1,500 because it is comparable, but, lower than the control cost for sources of volatile organic compounds (the other major ozone precursor)to comply with existing RACT regulations based on EPA's guidelines. For volatile organic compounds, required controls for existing sources are estimated to cost as much as $3,000 per ton removed.

Also, the cost of presumptive RACT emission limitations for utility boilers in other states have been estimated as $570 to $1,500. Finally, the costs to comply with the presumptive NOx RACT emission levels for other sources in other states is as much as $2,000 per ton removed. It should be noted for BACT determination for NOx emission sources the acceptable cost effectiveness have been as much as $4,000.

In addition to the average cost effectiveness of $1500/ton, the other factors such as the incremental cost effectiveness and other environmental impacts will also be considered in the RACT determination.

Therefore, the use of $1,500 as a target value for one of criteria in the determination of RACT is reasonable.

STEP 5 : Establishment of RACT Emission Limit

If enough uncertainty exists in establishing a final RACT emission limit with the control option chosen by the above procedure, the Department may establish a never-to-exceed preliminary emission limit. The

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preliminary emission limits for the electric utilities must generally not be less stringent than the emission limits recommended in the EPA's preliminary presumptive RACT levels for electric utility boilers. The final limit is established after adequate actual data is collected with the application of approved technology. The presumptive RACT technology for the coal-fired units with a heat input greater than or equal to 100 Million BTU per hour is "low-NOx burner with a separate OFA". The final limit will be established prior to issuing an operating permit based on the CEM or predictive modeling system or periodic stack test results. In the case of combustion units with a heat input greater than or equal to 250 Million BTU per hour, only a Department-approved CEM system is acceptable for the establishment of the final limit. The CEM system is intended to be any system which meets the performance specification included in the Department's Continuous Source Monitoring Manual. In the case of combustion units with a heat input greater than 100 Million BTU per hour but less than 250 Million BTU per hour source test results may be used in the establishment of limits and the compliance with such limit will be based on the average of three consecutive test runs. A periodic source testing will be required for the verification of the limit. As a minimum, the source testing will be required on annual basis. As the emission data base is established and the data consistently show compliance by a significant margin the testing frequency may be altered. However, the source owner/operator may opt for a predictive modeling program or a CEM system in lieu of periodic testing. The predictive modeling system shall identify and correlate various operating parameters with NOx emission levels through source testing. This predictive modeling program must be approved by the Department. The final limit will be set based upon the available data with an adequate margin for the normal fluctuation of emission levels. The averaging period is generally limited to a 24-hour average in order to protect the hourly ozone standard. Especially for larger sources, a daily averaging may be necessary to accommodate the normal fluctuations of the emission levels. However, the Department may establish a 30-day rolling average <u>in addition to</u> a daily average. The 30-day rolling average may be used to calculate annual baseline emissions for future offset generation. In certain cases the Department may accept the averaging period of 24-hour during the ozone season and a 30 day averaging period during the non-ozone season provided a satisfactory technical/economic justification was made. For the purpose of RACT compliance, the ozone season is defined as the period between April 1 to October 31. The detailed procedure can be found in section IV of this document.

Guidance for coal-fired units proposing to employ the presumptive RACT

For coal-fired combustion units with a rated heat input equal to or greater than 100 million Btus per hour, presumptive RACT requirements are the installation and operation of low-Nox burners with separated overfire air. A low-NOx burner with separated overfire air is defined as a burner design capable of reducing the formation of oxides of nitrogen (NOx) emissions through sub-stoichiometric combustion of fuel by means of a burner assembly consisting of two or more stages and the addition of

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secondary combustion air introduced downstream of the burner location. It is intended that the system be designed to employ the highest degree of staging practicable.

For example, in the case of a tangentially fired (T-fired) combustion unit proposing ABB's Low-NOx Concentric Firing System (LNCFS), presumptive RACT technology is the LNCFS III version unless it is shown that LNCFS III is not feasible either technically or economically. If a LNCFS system or an equivalent low-NOx burner with a SOFA, is proposed as RACT for a T-fired unit the RACT analysis need not address the feasibility of post combustion technologies. However, if LNCFS III is not proposed as RACT the RACT analysis must demonstrate satisfactorily that LNCFS III is not feasible.

Procedure to generate Emission Reduction Credits:

Emission reduction credit (ERC) is defined as a permanent, enforceable, quantifiable and specific reduction which can be considered as a reduction for the purpose of offsetting increases.

"Surplus" emission reductions are reductions not otherwise required by the applicable state implementation plan (SIP) and not already relied upon for SIP planning purposes, and not used by the source to meet any other regulatory requirements. Thus, emission reductions necessary to meet RACT or other statutory requirements such as acid rain limitations are not considered surplus and may not be creditable for emission offsets. In order for NOx emission reductions to be creditable, a federally enforceable RACT determination must have been made. Any reduction beyond the reductions required by RACT is eligible as surplus and thus available for netting or ERC banking purposes. As stated earlier RACT is defined as the <u>lowest</u> emission limitation that a particular source is capable of meeting by application of a control technology that is reasonably available. Therefore,"surplus" <u>cannot</u> be created with the approved RACT control option by merely achieving a lower emission level than the final limit without implementing additional control <u>measures</u> (not including the measures needed to optimize the selected RACT control option) or curtailment of operation. The "surplus" reductions can be achieved by any method, including curtailment of operation (operational limitation, production limits), improved control technologies or measures, shutdown or some combination thereof.

The following procedures will be followed to quantify creditable ERC's generated through the installation of control measures which are determined by the Department to be clearly more stringent than the RACT requirements. The emission reductions achieved via this "overcontrol" must necessarily be greater than reductions that would reasonably be expected from RACT measures.

1. The initial and most important task is to determine the appropriate RACT control technology and estimated emission level reflecting the application of the chosen RACT technology. The Department will use the available technical information in defining this technology and estimating

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the corresponding emission levels. RACT level will be the lowest emission limitation that a particular source is capable of meeting by application of a control technology that is reasonably available. It is also important that these estimated emission levels accurately reflect the maximum degree of control achieved or capable of achievement by similar sources that actually employ similar controls as RACT.

2. After the installation and emission testing of the "overcontrol" technology and establishment of the final NOx emission limit, the comparison will be made between this final emission limit achieved through "overcontrol" and the emission level previously determined for the Department-approved RACT control system. The difference between these two emission rates will be the emission rate used with the fuel consumption data to calculate creditable emission reductions.

3. If an applicant wishes to bank the ERCs due to "overcontrol" prior to installation of "overcontrol" technology, a federally enforceable NOx emission limit reflecting the "overcontrol" will be included in the plan approval. The difference between the NOx limit and the emission level previously determined for the Department-approved RACT control system will be the emission rate used with the fuel consumption data to calculate creditable emission reductions.

It should be noted that the new source which intends to use the ERCs created by the "overcontrol" of this existing source cannot commence **operation** until the successful implementation of the "overcontrol" technology.

Example: A utility might opt to install an SCR system in lieu of the presumptive RACT technology of LNB-SOFA system on a tangentially-fired boiler with a baseline emission rate of 0.80lb NOx/MMBtu. The existing data on LNB-SOFA on T-fired boilers indicate that up to 50% emission reduction could be achieved by this system. Therefore the the projected emission level after the application of RACT technology is 0.40lb NOx/MMBtu. After the SCR retrofit, the unit achieves an emission rate of 0.13 lb NOx/MMBtu. The difference between 0.40 and 0.13 or 0.27 lb NOx/MMBtu is the rate used with the fuel analysis and consumption data to calculate the creditable NOx ERC's.

III. NOx EMISSION AVERAGING FOR RACT COMPLIANCE:

The Department may approve emission averaging among facilities to provide flexibility in complying with the RACT requirements provided the following criteria are met:

1) The NOx emission reductions achieved through the RACT averaging plan must be no less than the emission reductions that would be achieved by complying with the RACT requirement on a source specific basis.

2) The averaging program shall include a tons per year emission

cap for each facility that in the aggregate is less than the aggregate of the emissions that would occur from each facility complying individually. In addition, each source shall have an emission rate limit such as lb/mmBTU to provide for independent verification and enforcement of the averaging program.

3) No credit shall be given for emission reductions that are achieved through the shutdown or curtailment of an operation included in the averaging program.

4) The ambient impact from the averaging program must be less than or equivalent to the impact from each source complying individually. This equivalence must be demonstrated both spatially and temporally.

5) The averaging program must be approved as a SIP revision prior to becoming effective.

6) The sources involved in the averaging program shall be required to continuously monitor and record the emissions. In addition the participating facilities are required to establish telemetry links between the facilities to provide real time emission data to all facilities affected by the averaging. For an averaging proposal involving sources at a single facility, the Department may approve alternate requirements provided the proposal demonstrates that the alternate methodologies are credible, workable, replicable and fully enforceable and adequately quantify emissions from all sources participating in the averaging program.

7) The emission averaging programs must be subject to an adequate enforcement mechanism. All the parties involved in the averaging should be held responsible for exceedances of the final RACT requirements.

Emission Averaging:

The emission averaging program may allow some emission sources to emit at a rate that is higher than the RACT rate (which was determined on a case-by-basis) as long as there is a compensating population of emission sources emitting at a rate that is lower than the RACT emission limitation. The allowable emission rate is proportional to the production level. The aggregate of actual emissions from the sources participating in the program must not exceed the aggregate of allowable emissions of those sources.

Air Quality Equivalence:

Traditionally, demonstrations of air quality equivalence required modeling. The modeling demonstrations may be waived, if:

1) the credit generating source in the averaging plan is located in an area with an equal or higher non-attainment designation than the credit consuming source; or,

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2) all sources included in the averaging plan are located within the attainment areas and located in the same broad vicinity; or,

3) all the sources included in the averaging plan are located within the same non-attainment area.

4) all the sources included in the averaging proposal which are not located within the same nonattainment area but are located less than 200 kilometers from any other source involved in the averaging proposal.

Step-by-Step Procedure:

1) Identify the RACT allowable emission levels for each source participating in the averaging plan through case-by-case analysis.

2) The Department sets an allowable source-specific emission rate for each source so that the following equation is met for the maximum allowable averaging period of 24 hours.

$\Sigma_{i=1-N}$ (Case-by-case RACT Allowable ER_i) x (Projected Activity $Level_i$) $\geq$
$\Sigma_{i=1-N}$ (Source Specific Allowable ER_i) x (Projected Activity $Level_i$)

Where i = each emission source participating in the averaging plan
N = the total number of emission units participating in the averaging plan.
Source Specific Allowable ER_i = Department imposed emission rate limit for emission $source_i$.

Projected activity $level_i$ = Estimate of future activity level for emission $source_i$

3) The aggregate of actual emissions from the sources participating in the plan must not exceed the aggregate of allowable emissions of those sources. The compliance will be verified by the following equation:

$\Sigma_{i=1-N}$ (Source Specific Allowable ER_i) x (Actual Activity $Level_i$)
$\geq \Sigma_{i=1-N}$ (Actual Emission $Rate_i$) x (Actual Activity $Level_i$)

IV. ESTABLISHMENT OF EMISSION LIMITATIONS FOR COAL-FIRED COMBUSTION UNITS WITH RATED HEAT INPUT GREATER THAN 100 MMBTU/HR:

Following the installation of approved RACT technology, Section 129.91 (j) requires the Department to determine the RACT emission limitation for combustion units with rated heat inputs greater than 100 MMBtu/hr. The determination of this maximum limit is to be based upon emissions data obtained either from approved continuous emission monitoring system or an alternate approved methodology. The following procedure shall be used for establishing the final RACT emission limit. The Department may approve an alternate methodology if it was demonstrated that the alternate methodology is more appropriate than the one included in the guidance document. In cases involving multiple sources emitting through a single stack, the methodology to establish the individual emission limits will be approved on a case-by-case basis.

1. A minimum of 90% valid daily averages for a period not less than six months and no more than a year is required. Conventionally, arithmetic average of hourly emission rate (lb/mmBTU) is used calculate the daily average. As an alternate, the facility may use the mass-weighted method, i.e. dividing the total mass of NOx emitted for the day by the total heat input over the same period. The CEM must be certified for the approved method.

A longer period (longer than a year) may be approved if it is demonstrated that a longer period is necessary to represent the normal operation.

2. The data from step one is to be subjected to the Shapiro-Wilk Test of Normality. In this test, data is to be subjected to analysis in two formats. First, the raw data is tested for normal distribution. Second, the existing data is converted to natural logs and tested for log-normal distribution. Based upon these two analysis, the distribution with the highest resulting Shapiro-Wilk statistic will become the distribution for determining the emission limit.

Note: Shapiro-Wilk routines are available through the SAS statistical programs.

3. If the Shapiro-Wilk's test indicates normal distribution, the arithmetic mean of daily average of the data will be used in the final emission limit calculation. The arithmetic mean of the data is defined as follows:

$$\text{Arithmetic mean} = \sum_{i=1}^{n} X_i/n$$

Where n = number of data points and X_i = i^{th} data point

If the Shapiro-Wilk's test indicates log-normal is the best distribution, then the geometric mean of the data will be used in the final emission calculation. The geometric mean is defined as:

$$\text{Geometric mean} = \exp\left[\sum^{n} \frac{(\ln X_i)}{n}\right]$$

Where exp = the natural antilog of the expression

4. The final emission limit is then determined from the following equation (based on one exceedence per year):

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For normally distributed data:

Emission rate = Arithmetic mean + (2.777 * Standard Deviation)

*
For log normally distributed data:

Emission rate = Median * $(\text{Geometric dispersion})^{2.777}$

Where Geometric dispersion = antilogarithm of standard deviation of the logarithm of data.

Median = 50th percentile of the distribution of x_i

The calculated emission limit must not generally exceed the preliminary limit imposed in the RACT approval.

Reference: Municipal Waste Combustion: Background Information for Promulgated Standards and Guidelines-Summary of Public Comments and Responses Appendices A to C, U.S. EPA, EPA-450/3-91-004, December 1990.

APPENDIX 2

NORTHEAST STATES FOR COORDINATED AIR USE MANAGEMENT (NESCAUM)

NESCAUM Stationary Source Committee Recommendation On NOx RACT for Industrial Boilers, Internal Combustion Engines and Combustion Turbines

September 18, 1992

The NESCAUM Stationary Source Review Committee is one of nine technical Committees established by the NESCAUM Board of Directors. The purpose of the committee is to provide an opportunity for engineers who review permits for new and existing sources to discuss common technical issues and provide some measure of consistency in the review of permits in the region. This recommendation has been developed in response to Sections 182(f) and 182(b)(2) of the Clean Air Act Amendments of 1990 (CAAA), which require states to impose Reasonably Available Control Technology (RACT) for sources that have the potential to emit nitrogen oxides (NOx) in excess of specified threshold amounts and are located in ozone nonattainment areas or in the ozone transport region. RACT is defined as follows:

> "the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility"

The CAAA requires states to develop and submit NOx RACT regulations to the US EPA by November 15, 1992. All regulated sources must be in compliance with the NOx RACT regulations by May 31, 1995.

In the Northeast, approximately 40 percent of the annual NOx emissions are from stationary sources and 60 percent are from mobile sources. NOx emissions react photochemically with volatile organic compounds (VOC) to form ground-level ozone. NOx emissions also react to form gaseous and particulate acids and other toxic air pollutants. Large portions of the NESCAUM region are currently in nonattainment for ozone, and up to 35 million people are exposed to unhealthy ozone levels each summer in the Northeast. The US EPA's Regional Oxidant Modeling for Northeast Transport (ROMNET) Report (June 1991), which is regarded as the most sophisticated analysis of the regional ozone problem, indicates that a NOx emission reduction of more than 55%, in conjunction with substantial VOC emission reductions, will be necessary to achieve the ozone health standard. In 1987, NOx emissions from all sources in the NESCAUM region totaled approximately 1.6 million tons. NOx emissions from the three source categories addressed in this recommendation constitute a large fraction of total NOx emissions in the NESCAUM region (ranging from 10 to 15% of total NOx emissions for individual states).

Based on this information and the requirement of 1990 CAAA, the committee has developed NOx RACT recommendations for: (1) Industrial Boilers, (2) Internal

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Combustion Engines, and (3) Combustion Turbines. The NOx RACT limits presented here attempt to account for variations in fuel type, design of combustion units and heat input rate.

For all units (industrial boilers, internal combustion engines, and combustion turbines) with high uncontrolled emission rates, which make a clear technical demonstration that NOx RACT emission limits are not feasible, states may set higher unit-specific alternative emission limitations. Such limitations would be based on the capabilities of all available and applicable technology for combustion modification.

NOx RACT for Industrial Boilers

Industrial boilers are steam-generating units that supply electric power and/or heat to an industrial, institutional or commercial operation, excluding boilers used by electric utilities to generate electricity.

The recommendation for NOx RACT for industrial boilers takes into account the maximum heat input rate of the boilers (in million of Btus/hour) and is as follows.

1. Small Boilers (Boilers < 50 MMBtu/hr)
   NOx RACT for small boilers will require appropriate adjustment of combustion process to minimize NOx emissions. The requirements for combustion adjustment will be developed by the individual states.

2. Medium-Size Boilers (Heat Input Rate ≥ 50 MMBtu/hr but less than 100 MMBtu/hr)

   a. For boilers in this size range burning wood, coal or some fuel other than oil or gas, NOx RACT will be determined by the individual states on a case-by-case basis.

   b. For boilers in this size range burning natural gas, the recommended NOx RACT limit is a performance-based standard of 0.10 lb/MMBtu, to be met on a 1-hour averaging basis.

   c. For boilers in this size range burning #2 oil, the recommended NOx RACT limit is a performance-based standard of 0.12 lb/MMBtu, to be met on a 1-hour averaging basis.

   d. For boilers in this size range burning #4, #5, or #6 oil, the recommended NOx RACT is a technology-based standard requiring joint application of low-NOx burners and flue gas recirculation (with minimum circulation of 10 percent). In addition, sources will be required periodically to provide the states with data on nitrogen content of #4, #5 or #6 oil (percent weight basis).

   e. For b) and c) above, the performance-based standards are to be met on an annual, one-hour source test basis at steady state, maximum load conditions (average of three, one-hour stack tests).

3. Large Boilers (Boilers ≥ 100 MMBtu/hr)
   The Committee recommends that all large industrial boilers, burning oil, gas coal or other fuels (for example wood), be treated the same as electric utility boilers and must

comply with NOx RACT for electric utilities boilers, as published by NESCAUM ("NESCAUM Stationary Source Committee Recommendation on NOx RACT for Utility Boilers," August 12, 1992).

NOx RACT for Internal Combustion Engines

The emission standards for internal combustion engines are for the control of NOx from existing internal combustion engines with a maximum heat input rate exceeding 3 MMBtu/hr. All proposed levels are based on a one-hour averaging period. Lean-Burn engines are those in which the amount of oxygen in the engine exhaust gases is 1.0% or more, by weight. Rich-burn engines are those in which the amount of oxygen in the engine exhaust gases is less than 1.0%, by weight. Rated brake horsepower (bhp) is as specified by the manufacturer and listed on the nameplate.

1. Rich-Burn Engines

   a. 1.5 grams per bhp-hr for gas-fired units

2. Lean-Burn Engines

   a. 2.5 grams per bhp-hr for gas-fired units

   b. 8 grams per bhp-hr for oil-fired units

The Stationary Source Review Committee believes that these NOx RACT limits are achievable through the application of three-way catalysts for rich-burn engines, and through the use of retarded engine timing or separate circuit after-cooling for lean-burn engines.

NOx RACT for Combustion Turbines

The emission standards outlined below are for the control of NOx from existing combustion turbines. The recommendation applies to combustion turbines rated at 25 MMBtu/hr or above (maximum heat input rate).

The proposed levels are based on a one-hour averaging period.

1. Simple Cycle Combustion Turbines

   a. 55 parts per million volume dry (ppvmd) (corrected to 15% oxygen) for gas-fired turbines without oil back-up.

   b. 75 ppmvd (corrected to 15% oxygen) for oil-fired turbines

   c. for gas-fired turbines with oil back-up:
      1. 55 ppmvd (15% oxygen) when operating on gas
      2. 75 ppmvd (15% oxygen) when operating on oil

2. Combined Cycle Combustion Turbines

   a. 42 ppmvd (corrected to 15 % oxygen) for gas-fired turbines without oil back-up

b. 65 ppmvd (corrected to 15% oxygen) for oil-fired turbines

c. For gas-fired turbines with oil back-up:
   1. 42 ppmvd (15% oxygen) when operating on gas
   2. 65 ppmvd (15% oxygen) when operating on oil

The Stationary Source Review Committee believes that these NOx RACT limits are achievable through the application of water or steam injection and dry low-NOx combustion technology. Higher emission limits may be specified for an individual unit, on a case-by-case basis, if the owner of the stationary combustion turbine can make a demonstration that water injection is not feasible or that low-NOx combustors are not available for the make and model of turbine. Water injection not being feasible refers to either the unavailability of water (i.e., restrictions placed on water use), excessive costs associated with purifying the water (i.e., cleaning up salt water) or other factors associated with either the turbine or the location of the turbine, at the discretion of the states and the US EPA.

These recommendations were adopted by the NESCAUM Board of Directors on September 17, 1992.

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LNB Cost analysis for combustion unit greater than 20 and less than 50 MMBtu/hr			
Boiler Size (MMBtu/hr)	20	50	Reference
DIRECT COSTS			
Equipment Cost	$128,700	$128,700	Washington State Dept of Ecology (2006) adjusted with CPI for 2020
Instrumenttation and Monitoring	$12,870	$12,870	(Typical 10% of EC)
Freight	$7,722	$7,722	6% of EC
Tax	$7,722	$7,722	6% of EC
Total Purchsed Equipment Cost (TEC)	$157,014	$157,014	
Direct Installation Cost			
Foundation and Support	$12,561	$12,561	8% of TEC
Handling and Erection	$21,982	$21,982	14% of TEC
Electric	$6,281	$6,281	4% of TEC
Piping	$3,140	$3,140	2% of TEC
Painting	$1,570	$1,570	1% of TEC
Indirect Installation Costs			
Engineering and Supervision	$15,701	$15,701	10% of TEC
Construction and Field Expenses	$7,851	$7,851	5% of TEC
Contractor fees	$15,701	$15,701	10% of TEC
Contingencies	$4,710	$4,710	3% of TEC
Other Indirect Costs			
Startup and Testing	$4,710	$4,710	3% of TEC
TOTAL CAPITAL COST (TCC)	$251,222	$251,222	
Direct Annual Costs			
Electricity	$26,280	$26,280	Vendor's assumption of $52.580 for 100 MMBtu/hr boiler
Material & Maintenance	$12,561	$12,561	5% of TCC (Most vendors)
Indirect Annual Costs			
Overhead	$7,537	$7,537	60% of Maintenance (EPA's OAQPS)
PropertyTax+Ins.+Admn.	$10,049	$10,049	(4% of TCC - OAQPS)
Capital Recovery (5.5% @ 20 yrs)	$21,027	$21,027	
TOTAL ANNUALIZED COST	$77,454	$77,454	
Uncontrolled NOx emissions (lb/MMBtu)	0.2	0.2	
Uncontrolled NOx emissions (tons/year)	17.52	43.80	
NOx removed TPY (50% Eff.)	8.76	21.90	
COST EFFECTIVENESS ($/Ton of NOx removed)	$8,841.78	$3,536.71	

Oxidation Catalyst cost analysis for combustion unit greater than 20 and less than 50 MMBtu/hr			
Boiler Size (MMBtu/hr)	20	50	Reference
DIRECT COSTS			
Equipment Cost	$232,788	$232,788	Grays Harbor Energy Project for 30 MMBtu/hr auxiliary boiler
Instrumenttation and Monitoring	$23,279	$23,279	(Typical 10% of EC)
Freight	$13,967	$13,967	6% of EC
Tax	$13,967	$13,967	6% of EC
Total Purchsed Equipment Cost (TEC)	$284,002	$284,002	
Direct Installation Cost			
Foundation and Support	$22,720	$22,720	8% of TEC
Handling and Erection	$39,760	$39,760	14% of TEC
Electric	$11,360	$11,360	4% of TEC
Piping	$5,680	$5,680	2% of TEC
Painting	$2,840	$2,840	1% of TEC
Indirect Installation Cost			
Engineering and Supervision	$28,400	$28,400	10% of TEC
Construction and Field Expenses	$14,200	$14,200	5% of TEC
Contractor fees	$28,400	$28,400	10% of TEC
Contingencies	$8,520	$8,520	3% of TEC
Other Indirect Costs			
Startup and Testing	$8,520	$8,520	3% of TEC
TOTAL CAPITAL COST (TCC)	$454,403	$454,403	
Direct Annual Costs			
Electricity	$5,226	$5,226	$1,500 for 2500 hrs operation
Catalyst replacement	$5,000	$5,000	
Material & Maintenance	$22,720	$22,720	5% of TCC (Most vendors)
Indirect Annual Costs			
Overhead	$13,632	$13,632	60% of Maintenance (EPA's OAQPS)
PropertyTax+Ins.+Admn.	$18,176	$18,176	(4% of TCC - OAQPS)
Capital Recovery (5.5% @ 20 yrs)	$38,034	$38,034	
TOTAL ANNUALIZED COST	$102,788	$102,788	
Uncontrolled VOC emissions (lb/MMBtu)	0.0036	0.0036	VOC emission at 3 ppm corrected at 3% oxygen
Uncontrolled VOC emissions (tons/year)	0.32	0.79	
VOC removed TPY (50% Eff.)	0.16	0.39	
COST EFFECTIVENESS ($/Ton of VOC removed)	$651,876.31	$260,750.52	

APPENDIX 4

LNB Cost analysis for combustion unit with uncontrolled NOx emission at 5 tons per year		
Boiler Size (MMBtu/hr)	50	Reference
DIRECT COSTS		
Equipment Cost	$128,700	Washington State Dept of Ecology (2006) adjusted with CPI for 2020
Instrumenttation and Monitoring	$12,870	(Typical 10% of EC)
Freight	$7,722	6% of EC
Tax	$7,722	6% of EC
Total Purchsed Equipment Cost (TEC)	$157,014	
Direct Installation Cost		
Foundation and Support	$12,561	8% of TEC
Handling and Erection	$21,982	14% of TEC
Electric	$6,281	4% of TEC
Piping	$3,140	2% of TEC
Painting	$1,570	1% of TEC
Indirect Installation Cost		
Engineering and Supervision	$15,701	10% of TEC
Construction and Field Expenses	$7,851	5% of TEC
Contractor fees	$15,701	10% of TEC
Contingencies	$4,710	3% of TEC
Other Indirect Costs		
Startup and Testing	$4,710	3% of TEC
TOTAL CAPITAL INVESTMENT (TCI)	$251,222	
Direct Annual Costs		
Electricity	$26,280	Vendor's assumption of $52.580 for 100 MMBtu/hr boiler
Material & Maintenance	$12,561	5% of TCI (Most vendors)
Indirect Annual Costs		
Overhead	$7,537	60% of Maintenance (EPA's OAQPS)
PropertyTax+Ins.+Admn.	$10,049	(4% of TCI - OAQPS)
Capital Recovery (5.5% @ 20 yrs)	$21,027	
TOTAL ANNUALIZED COST	$77,454	
Uncontrolled NOx emissions (tons/year)	5.00	
NOx removed TPY (50% Eff.)	2.50	
COST-EFFECTIVENESS ($/Ton NOx removed)	$30,981.60	

Oxidation Catalyst cost analysis for combustion unit with uncontrolled VOC emission at 2.7 tons per year		
Boiler Size (MMBtu/hr)	50	Reference
DIRECT COSTS		
Equipment Cost	$232,788	Grays Harbor Energy Project for 30 MMBtu/hr auxiliary boiler
Instrumenttation and Monitoring	$23,279	(Typical 10% of EC)
Freight	$13,967	6% of EC
Tax	$13,967	6% of EC
Total Purchsed Equipment Cost (TEC)	$284,002	
Direct Installation Cost		
Foundation and Support	$22,720	8% of TEC
Handling and Erection	$39,760	14% of TEC
Electric	$11,360	4% of TEC
Piping	$5,680	2% of TEC
Painting	$2,840	1% of TEC
Indirect Installation Cost		
Engineering and Supervision	$28,400	10% of TEC
Construction and Field Expenses	$14,200	5% of TEC
Contractor fees	$28,400	10% of TEC
Contingencies	$8,520	3% of TEC
Other Indirect Costs		
Startup and Testing	$8,520	3% of TEC
TOTAL CAPITAL INVESTMENT (TCI)	$454,403	
Direct Annual Costs		
Electricity	$5,226	$1,500 for 2500 hrs operation
Catalyst replacement	$5,000	
Material & Maintenance	$22,720	5% of TCI (Most vendors)
Indirect Annual Costs		
Overhead	$13,632	60% of Maintenance (EPA's OAQPS)
PropertyTax+Ins.+Admn.	$18,176	(4% of TCI - OAQPS)
Capital Recovery (5.5% @ 20 yrs)	$38,034	
TOTAL ANNUALIZED COST	$102,788	
Uncontrolled VOC emissions (tons/year)	2.70	
VOC removed TPY (50% Eff.)	1.35	
COST-EFFECTIVENESS ($/Ton VOC removed)	$76,139.15	

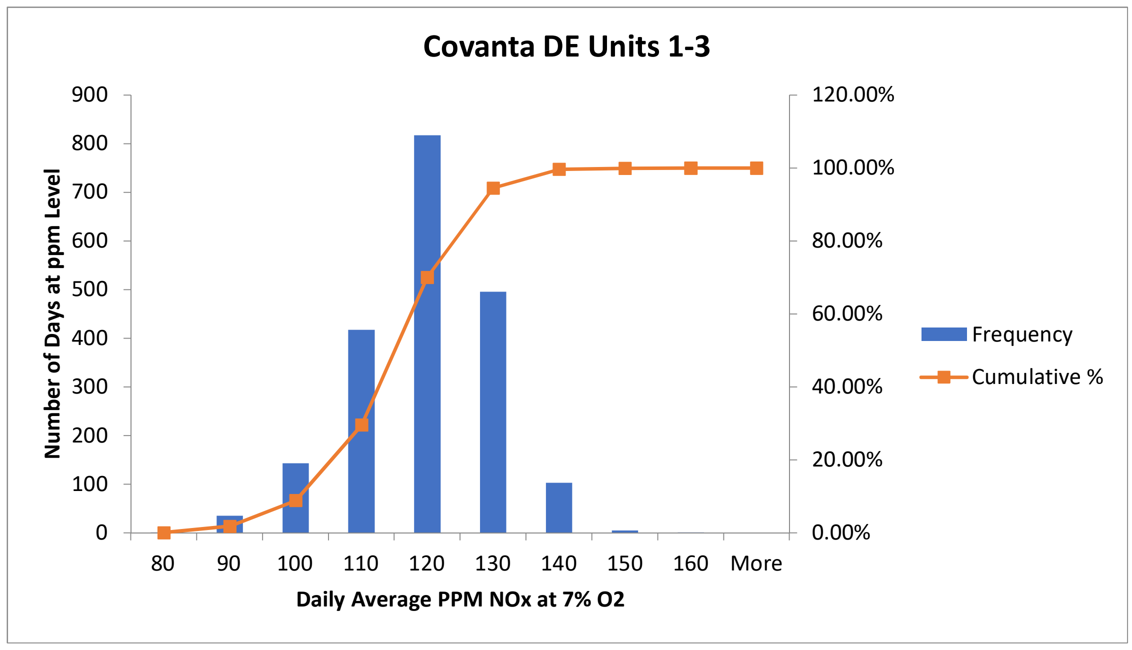
APPENDIX 5

Cost Analysis for SNCR for Municipal Waste Combustor		
Cost estimate	Assumed average large MWC in PA	Factors Used
Daily throughput municipal waste (tpd waste)	500	Asumed average large combustor (Range 300 - 600 tpd)
Hrs/Yr	8760	
Reference NOx emissions in lbs/hr	109.00	Permit limit for Covanta Plymouth 109 lb/hr and 180 ppm@7%O2
NOx emissions in lbs/hr	90.80	Calculated from cell above for 150 ppm@7% O2
Total Capital Cost	$1,392,000	Based on $464,000 for 200 tpd MWC at Olmstead, MN for 2007
TOTAL CAPITAL COST (TCC)	$1,726,080.00	With CPI from 2007 - 2020 (1.24)
Direct Annual Costs		
Elecricity	$95,124	$0.0676 kw/hr
Chemical Cost (Urea/Ammonia)	$88,500	Based on $29,500 for 200 tpd MWC at Olmstead, MN for 2007
Administration (3% of maintenance+labor)	$3,154	3% of maintenance +labor
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	100% of maintenance labor
Indirect Annual Costs		
Annulized Capital Recovery Cost (20 yrs at 5.5%)	$144,473	TCC*0.0837
Property Taxes (1% of TCC-OAQPS)	$17,261	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$17,261	1% of TCC (OAQPS)
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$470,892	This is cloose to Annual Operating cost*3 for Olmstead for 200 tpd MWC
Uncontrolled NOx TPY	397.70	
NOx removed TPY (30% Eff.)	119.31	
COST-EFFECTIVENESS ($/Ton NOx removed)	$3,946.75	

APPENDIX 6

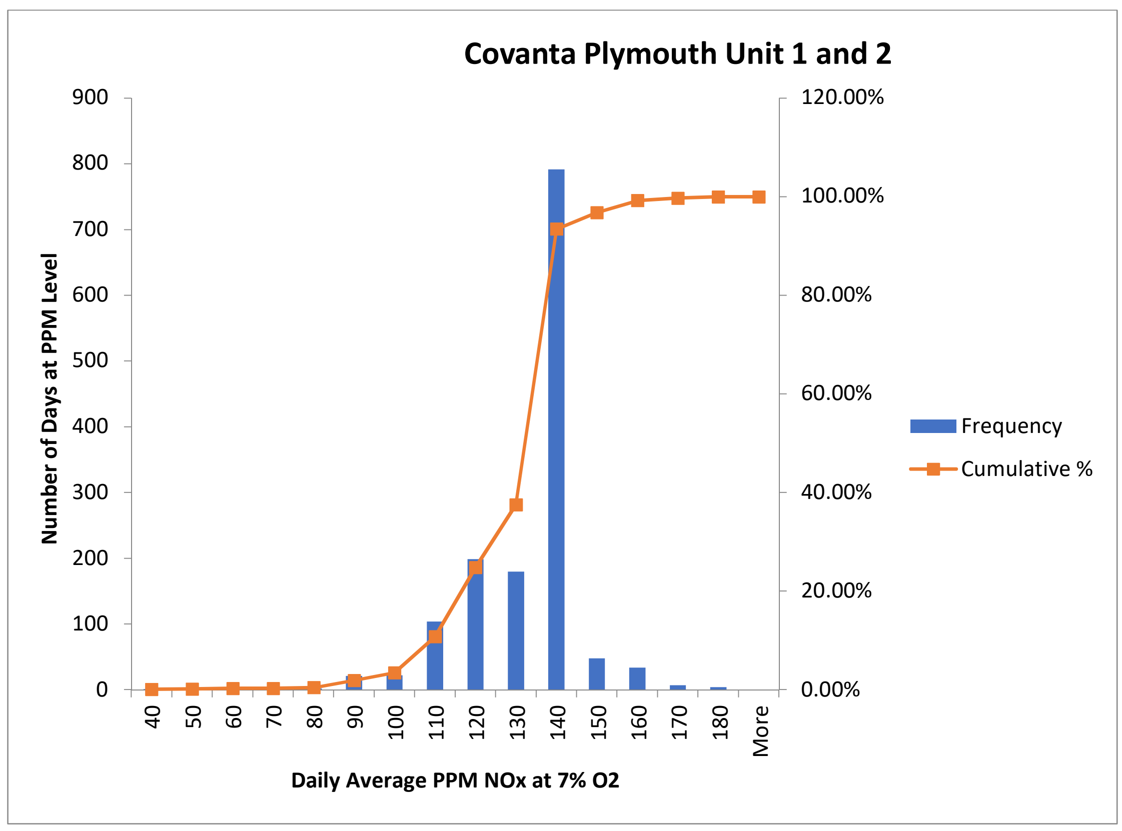
NOx emission test results from all MWCs for 2018 and 2019

Bin	Frequency	Cumulative %
80	1	0.05%
90	35	1.78%
100	143	8.86%
110	418	29.55%
120	818	70.05%
130	496	94.60%
140	103	99.70%
150	5	99.95%
160	1	100.00%
More	0	100.00%

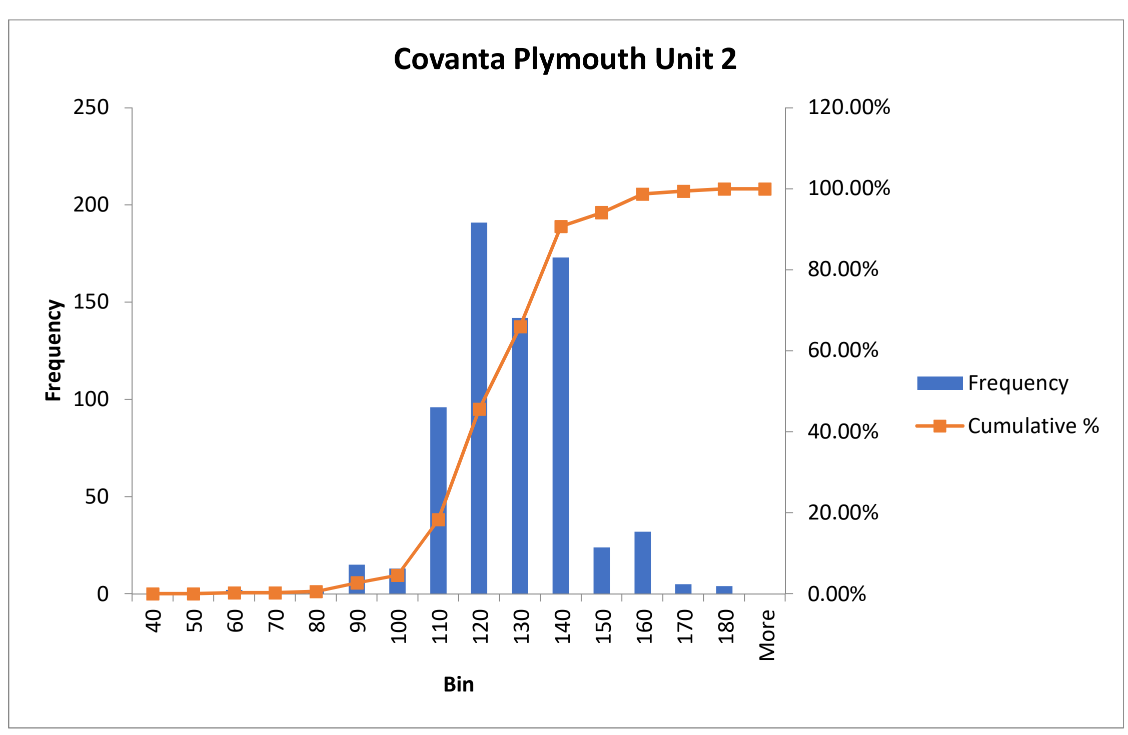


Bin	Frequency	Cumulative %
40	1	0.07%
50	1	0.14%
60	2	0.28%
70	0	0.28%
80	2	0.42%
90	21	1.91%
100	22	3.46%
110	104	10.80%
120	199	24.84%
130	180	37.54%
140	792	93.44%
150	48	96.82%
160	34	99.22%
170	7	99.72%
180	4	100.00%
More	0	100.00%

45 days over 150 PPM Nox
41 days occurred on unit 2
All but 5 of the 42 days occurred from 11/7/2019 to 1/8/2020

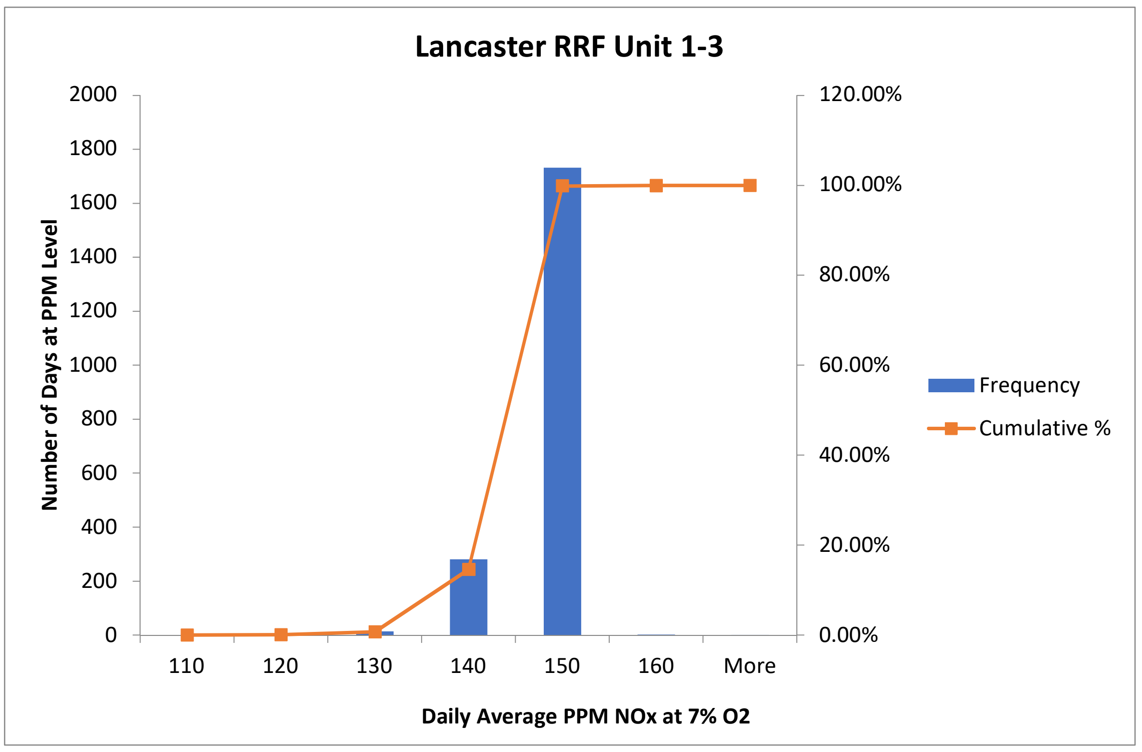


Bin	Frequency	Cumulative %
40	0	0.00%
50	0	0.00%
60	2	0.29%
70	0	0.29%
80	2	0.57%
90	15	2.72%
100	13	4.58%
110	96	18.31%
120	191	45.64%
130	142	65.95%
140	173	90.70%
150	24	94.13%
160	32	98.71%
170	5	99.43%
180	4	100.00%
More	0	100.00%

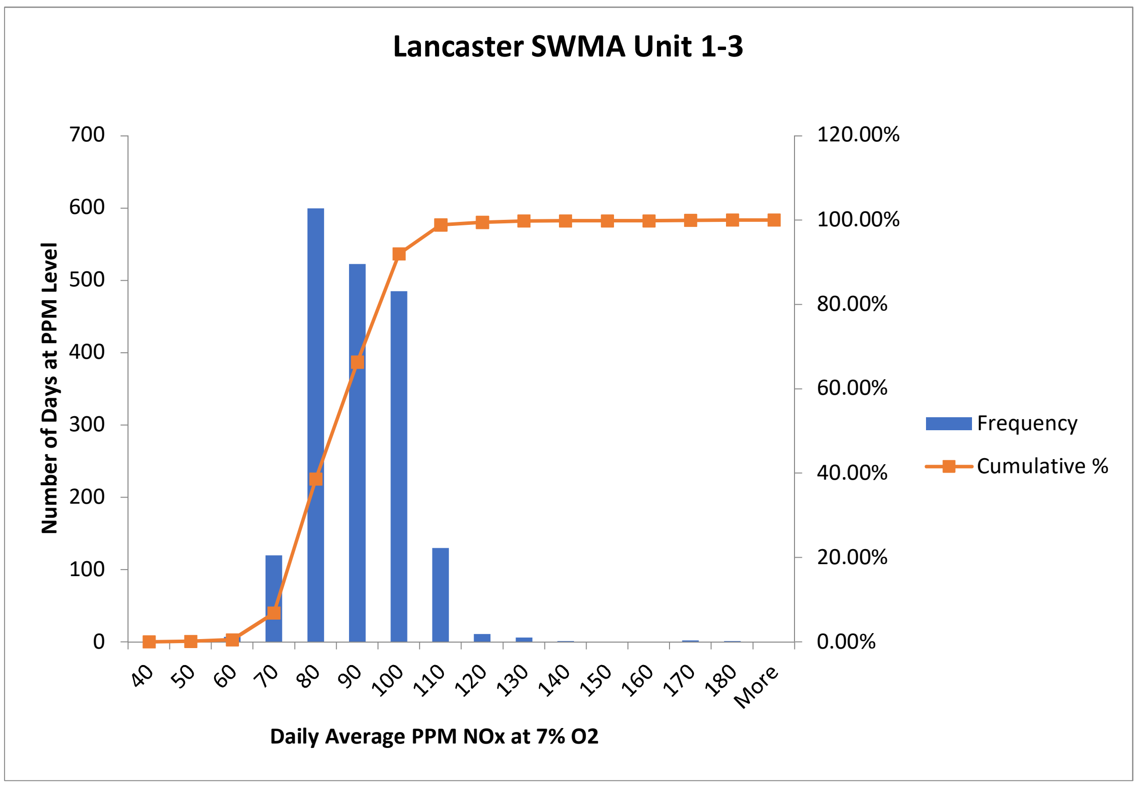


APPENDIX 6

Bin	*Frequency*	*Cumulative %*
110	0	0.00%
120	1	0.05%
130	14	0.74%
140	281	14.57%
150	1733	99.85%
160	2	99.95%
More	1	100.00%

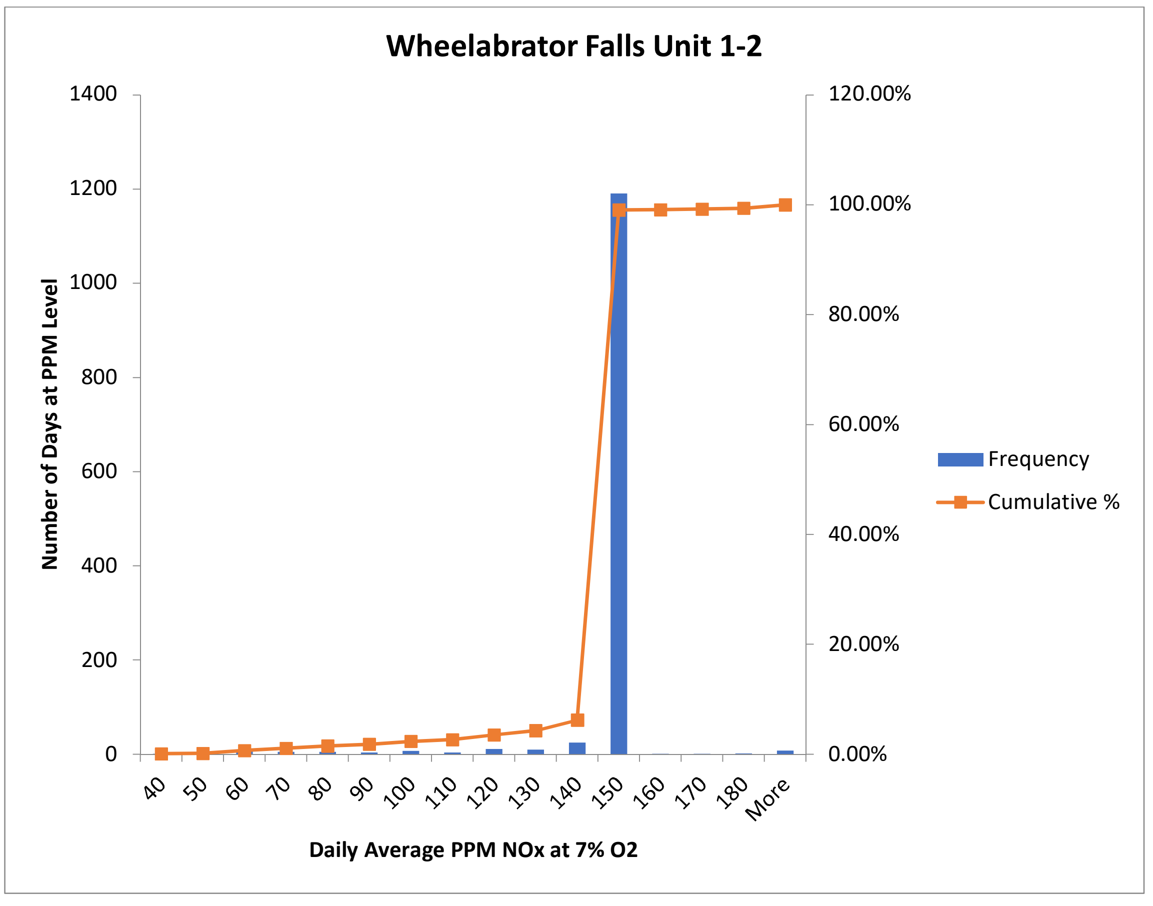


Bin	*Frequency*	*Cumulative %*
40	0	0.00%
50	2	0.11%
60	7	0.48%
70	120	6.83%
80	600	38.61%
90	523	66.31%
100	485	92.00%
110	130	98.89%
120	11	99.47%
130	6	99.79%
140	1	99.84%
150	0	99.84%
160	0	99.84%
170	2	99.95%
180	1	100.00%
More	0	100.00%



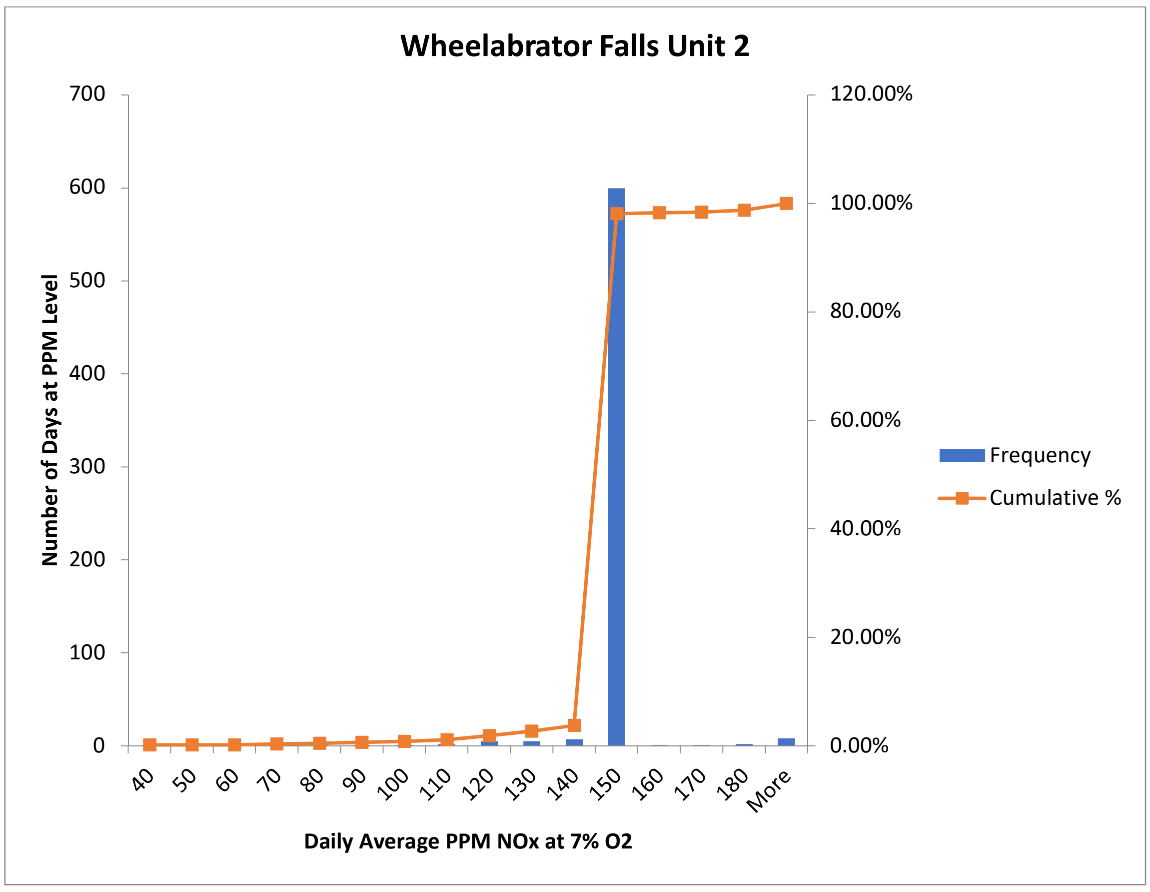
Bin	*Frequency*	*Cumulative %*
40	1	0.08%
50	1	0.16%
60	7	0.70%
70	5	1.09%
80	5	1.48%
90	4	1.79%
100	7	2.34%
110	4	2.65%
120	11	3.51%
130	10	4.29%
140	25	6.24%
150	1191	99.06%
160	1	99.14%
170	1	99.22%
180	2	99.38%
More	8	100.00%

12 days over 150 PPM Nox
Al occurred on unit 2



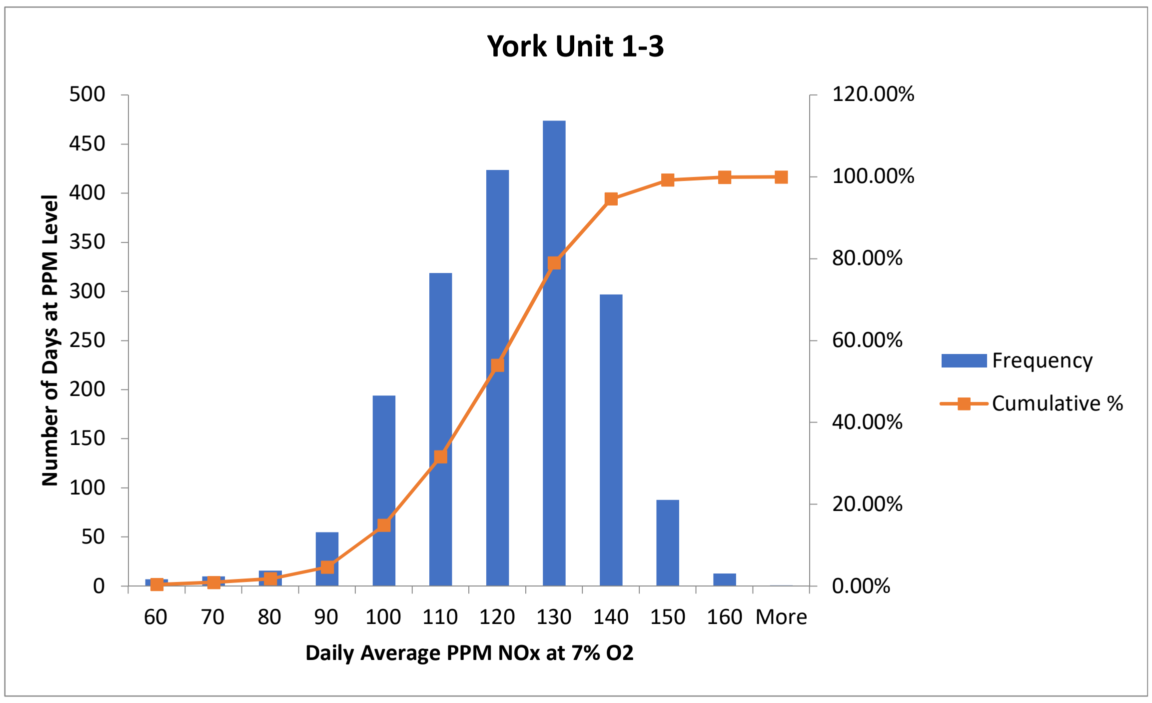
APPENDIX 6

Bin	Frequency	Cumulative %
40	1	0.16%
50	0	0.16%
60	0	0.16%
70	1	0.31%
80	1	0.47%
90	1	0.63%
100	1	0.79%
110	2	1.10%
120	5	1.89%
130	5	2.67%
140	7	3.77%
150	600	98.11%
160	1	98.27%
170	1	98.43%
180	2	98.74%
More	8	100.00%

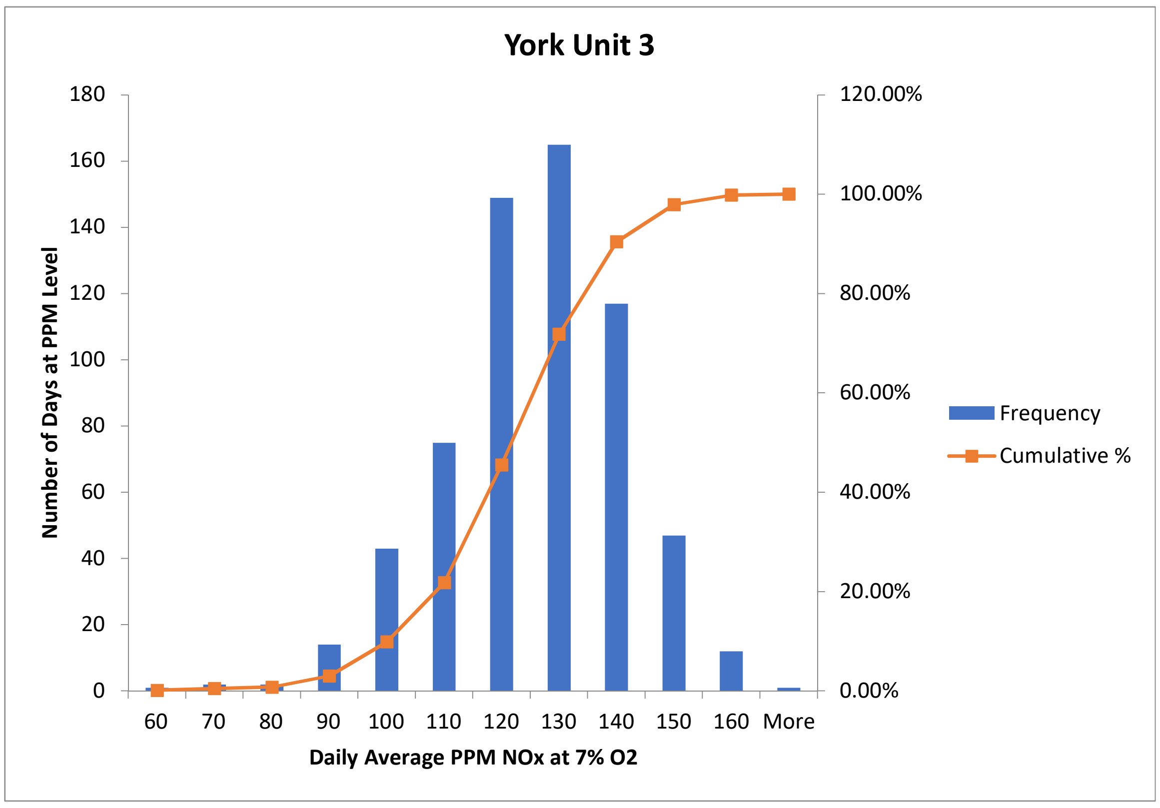


Bin	Frequency	Cumulative %
60	7	0.37%
70	10	0.90%
80	16	1.74%
90	55	4.64%
100	194	14.86%
110	319	31.66%
120	424	54.00%
130	474	78.98%
140	297	94.63%
150	88	99.26%
160	13	99.95%
More	1	100.00%

14 days over 150 PPM Nox
13 days occurred on unit 3
Al but 2 of the 13 days occurred from 4/18/2018 to 5/20/2018



Bin	Frequency	Cumulative %
60	1	0.16%
70	2	0.48%
80	2	0.80%
90	14	3.03%
100	43	9.87%
110	75	21.82%
120	149	45.54%
130	165	71.82%
140	117	90.45%
150	47	97.93%
160	12	99.84%
More	1	100.00%



APPENDIX 7

Cost Analysis for SCR for NG, propane, or liquid petroleum gas-fired combustion unit or process heater			
Boiler Capacity MMBtu/hr	50	250	Factors/Reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.1	0.1	
TOTAL CAPITAL COST (TCC) in 2016	$1,884,950	$5,365,750	EPA cost spreadsheet for 50 MMBtu and 250 MMBtu/hr for 2016
TOTAL CAPITAL COST (TCC)	$2,054,596	$5,848,668	TCC in 2020 with CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Elecricity	$16,595.25	$82,975.16	EPA cost spreadsheet for 50 MMBtu and 250 MMBtu/hr for 2016
Chemical Cost (Urea/Ammonia)	$9,156.00	$45,778.91	EPA cost spreadsheet for 50 MMBtu and 250 MMBtu/hr for 2016
Catalyst Replacement (costs/No. of years)	$4,738.23	$23,691.15	EPA cost spreadsheet for 50 MMBtu and 250 MMBtu/hr for 2016
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% ofmaintenance +labor
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$141,356	$402,388	TCC*0.0688
Property Taxes (1% of TCC-OAQPS)	$20,546	$58,487	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$20,546	$58,487	1% of TCC (OAQPS)
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$321,211	$780,080	
Uncontrolled NOx TPY	21.90	109.50	
NOx removed TPY (80% Eff.)	18	88	
COST-EFFECTIVENESS ($/Ton NOx removed)	$18,334	$8,905	

APPENDIX 8

SCR Cost Analysis for distillate oil-fired combustion unit or process heater greater than 50 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.12	0.12	
TOTAL CAPITAL COST (TCC) in 2016	$1,557,377	$4,433,271	EPA cost spreadsheet for 50 and 250 MMBtu
TOTAL CAPITAL COST (TCC) in 2020	$1,697,541	$4,832,265	With CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Elecricity	$18,829.75	$94,146.57	EPA cost spreadsheet for 50 and 250 MMBtu
Chemical Cost (Urea/Ammonia)	$10,987.20	$54,934.91	EPA cost spreadsheet for 50 and 250 MMBtu
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Catalyst Replacement (costs/No. of years)	$4,773.11	$23,863.37	EPA cost spreadsheet for 50 and 250 MMBtu
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% of maintenance+labor
Property Taxes (1% of TCC-OAQPS)	$16,975	$48,323	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$15,574	$44,333	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$116,791	$332,460	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$292,204	$706,334	
Uncontrolled NOx TPY	26.28	131.40	
NOx removed TPY (80% Eff.)	21	105	
COST-EFFECTIVENESS ($/Ton NOx removed)	$13,899	$6,719	

APPENDIX 9

SCR Cost Analysis for residual oil or other liquid-fired combustion unit or process heater greater than 50 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.2	0.2	
TOTAL CAPITAL COST (TCC) in 2016	$1,557,377	$4,433,271	EPA cost spreadsheet for 50 and 250 MMBtu for 2016
TOTAL CAPITAL COST (TCC) in 2020	$1,697,541	$4,832,265	With CPI 1.09
Direct Annual Costs			
Elecricity	$18,829.75	$94,146.57	EPA cost spreadsheet for 50 and 250 MMBtu for 2016
Chemical Cost (Urea/Ammonia)	$18,312.00	$114,446.73	EPA cost spreadsheet for 50 and 250 MMBtu for 2016
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Catalyst Replacement (costs/No. of years)	$4,910.45	$24,980.62	EPA cost spreadsheet for 50 and 250 MMBtu for 2016
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% of maintenance+labor
Property Taxes (1% of TCC-OAQPS)	$16,975	$48,323	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$15,574	$48,323	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$116,791	$332,460	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$299,666	$770,953	
Uncontrolled NOx TPY	43.80	219.00	
NOx removed TPY (80% Eff.)	35	175	
COST-EFFECTIVENESS ($/Ton NOx removed)	$8,552	$4,400	

APPENDIX 10

SCR Cost Analysis for refinery gas-fired combustion unit or process heater				
Boiler Capacity MMBtu/hr	50	250	500	Factors/Reference used
Hrs/Yr	8760	8760	8760	
NOx emissions (lb/MMBtu)	0.25	0.25	0.25	
TOTAL CAPITAL COST (TCC) in 2016	$1,884,950	$5,365,750	$10,731,500	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
TOTAL CAPITAL COST (TCC) in 2020	$2,054,596	$5,848,668	$11,697,335	With CPI 1.09 from 2016 to 2020
Direct Annual Costs				
Elecricity	$16,595.25	$82,975	$165,950.32	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	$32,850	100% of maintenance labor
Chemical Cost (Urea/Ammonia)	$22,888.91	$114,447	$228,893.46	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Catalyst Replacement (costs/No. of years)	$4,996.56	$24,981	$49,961.24	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Indirect Annual Costs				
Administration (3% of maintenance+labor)	$3,154	$3,154	$3,154	3% of maintenance + labor
Property Taxes (1% of TCC-OAQPS)	$20,546	$58,487	$107,315	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$20,546	$58,487	$107,315	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$129,685	$369,164	$799,497	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$323,531	$816,813	$1,567,205	
Uncontrolled NOx TPY	54.75	273.75	547.50	
NOx removed TPY (80% Eff.)	44	219	438	
COST-EFFECTIVENESS ($/Ton NOx removed)	$7,387	$3,730	$3,578	

APPENDIX 11

SCR Cost Analysis for coal-fired combustion unit between 50 - 250 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/Reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.45	0.45	
TOTAL CAPITAL COST (TCC) in 2016	$4,806,258	$13,280,762	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
TOTAL CAPITAL COST (TCC) in 2020	$5,238,821	$14,476,031	With CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$360,431	$995,951	TCC*0.0688
Elecricity	$18,073.29	$90,366	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Chemical Cost (Urea/Ammonia)	$41,200.91	$206,005	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Catalyst Replacement (costs/No. of years)	$17,468.34	$19,763	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% ofmaintenance +labor
Property Taxes (1% of TCC-OAQPS)	$52,388	$144,760	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$52,388	$144,760	1% of TCC (OAQPS)
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$650,223	$1,709,879	
Uncontrolled NOx TPY	98.55	492.75	
NOx removed TPY (80% Eff.)	79	394	
COST-EFFECTIVENESS ($/Ton NOx removed)	$8,247	$4,338	

APPENDIX 12

SNCR Cost Analysis for coal-fired combustion unit between 50 - 250 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/Reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.45	0.45	
TOTAL CAPITAL COST (TCC) in 2016	$1,766,776	$4,045,623	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
TOTAL CAPITAL COST (TCC) in 2020	$1,925,786	$4,409,729	With CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Elecricity	$832.76	$4,164	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Water Cost	$683.43	$3,419	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Ash Cost	$263.78	$1,318	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Fuel Cost	$3,325.59	$16,628	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Chemical Cost (Urea/Ammonia)	$59,838.82	$299,196	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% of maintenance +labor
Property Taxes (1% of TCC-OAQPS)	$19,258	$44,097	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$19,258	$44,097	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$121,554	$278,339	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$333,288	$799,532	
Uncontrolled NOx TPY	98.55	492.75	
NOx removed TPY (30% Eff.)	30	148	
COST-EFFECTIVENESS ($/Ton NOx removed)	$11,273	$5,409	

APPENDIX 13

Control technology	Control efficiency	Uncontrolled emission level lb/Mmbtu	Size of boiler Mmbtu/hr	Cost per ton of NOx 2016	Cost per ton of NOx 2020
SNCR	30%	0.16	250	$5,747	$6,207
SNCR	30%	0.16	500	$4,395	$4,747

SAMPLE CALCULATION

Data Inputs

Enter the following data for your combustion unit:

Is the combustion unit a utility or industrial boiler? Industrial

What type of fuel does the unit burn? Coal

Is the SNCR for a new boiler or retrofit of an existing boiler Retrofit

Please enter a retrofit factor equal to or greater than 0.84 based on the level of difficulty. Enter 1 for projects of average retrofit difficulty. 1

Complete all of the highlighted data fields:

What is the maximum hea | 250 MMBtu/hour

What is the higher heating | 6,000 Btu/lb

What is the estimated actual annual fuel consumption? | 365,000,000 lbs/year

Is the boiler a fluid-bed boile | Yes

Enter the net plant heat in | 10 MMBtu/MW

If the NPHR is not known,

Fuel Type	Default NPHR
Coal	10 MMBtu/MW
Fuel Oil	11 MMBtu/MW
Natural Gas	8.2 MMBtu/MW

Provide the following information for coal-fired boilers:

Type of coal burned: Lignite

Enter the sulfur content (%S) = 1.84 percent by weight

or Select the appropriate SO_2 emission rate: Not Applicable

*The sulfur content of 1.84% is a default value. See below for data source. Enter actual value, if known.

Ash content (%Ash): 9.23 percent by weight

*The ash content of 9.23% is a default value. See below for data source. Enter actual value, if known.

For units burning coal blends:

Note: The table below is pre-populated with default values for HHV, %S, %Ash and cost. Please enter the actual values for these parameters in the table below. If the actual value for any parameter is not known, you may use the default values provided.

	Fraction in Coal Blend	%S	%Ash	HHV (Btu/lb)	Fuel Cost ($/MMBtu)
Bituminous	0	1.84	9.23	11,841	2.4
Sub-Bituminous	0	0.41	5.84	8,826	1.89
Lignite	0	0.82	13.6	6,626	1.74

Please click the calculate button to calculate weighted values based on the data in the table above.

Enter the following design parameters for the proposed SNCR:

Number of days the SNCR | 365 days

Plant Elevation | 250 Feet above sea level

Inlet NO_x Emissions (NOx_{in} | 0.16 lb/MMBtu

Oulet NO_x Emissions (NOx_o | 0.112 lb/MMBtu

Estimated Normalized Stoi | 1.22

Concentration of reagent a | 29 Percent

Density of reagent as store | 56 lb/ft^3

Concentration of reagent i | 10 percent

Number of days reagent is | 14 days

Estimated equipment life | 30 Years

Select the reagent used | Ammonia

Densities of typical SNCR reagents:	
50% urea solution	71 lbs/ft^3
29.4% aqueous NH_3	56 lbs/ft^3

Enter the cost data for the proposed SNCR:

Desired dollar-year | 2016

CEPCI for 2016 | 541.7 | 541.7 | 2016 CEPCI | CEPCI = Chemical Engineering Plant Cost Index

Annual Interest Rate (i) | 5.5 Percent*

* 5.5 percent is the default bank prime rate. User should enter current bank prime rate (available at https://www.federalreserve.gov/releases/h15/.)

Fuel ($Cost_{fuel}$) | 2.40 $/MMBtu*

Reagent ($Cost_{reag}$) | 0.29 $/gallon for a 29 percent solution of ammonia

Water ($Cost_{water}$) | 0.0042 $/gallon*

Electricity ($Cost_{elect}$) | 0.0676 $/kWh*

Ash Disposal (for coal-fired | 48.80 $/ton*

* The values marked are default values. See the table below for the default values used and their references. Enter actual values, if known.

Note: The use of CEPCI in this spreadsheet is not an endorsement of the index, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

Maintenance and Administrative Charges Cost Factors:

Maintenance Cost Factor (| 0.015

Administrative Charges Fa | 0.03

Data Sources for Default Values Used in Calculations:

Data Element	Default Value	Sources for Default Value	If you used your own site-specific values, please enter the value used and the reference source . . .
Reagent Cost ($/gallon)	$0.293/gallon of 29% Ammonia	U.S. Geological Survey, Minerals Commodity Summaries, January 2017 (https://minerals.usgs.gov/minerals/pubs/commodity/nitrogen/mcs-2017-nitro.pdf	
Water Cost ($/gallon)	0.00417	Average water rates for industrial facilities in 2013 compiled by Black & Veatch. (see 2012/2013 "50 Largest Cities Water/Wastewater Rate Survey." Available at http://www.saws.org/who_we_are/community/RAC/docs/2014/50-largest-cities-brochure-water-wastewater-rate-survey.pdf.	
Electricity Cost ($/kWh)	0.0676	U.S. Energy Information Administration. Electric Power Monthly. Table 5.3. Published December 2017. Available at: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.	
Fuel Cost ($/MMBtu)	2.40	U.S. Energy Information Administration. Electric Power Annual 2016. Table 7.4. Published December 2017. Available at: https://www.eia.gov/electricity/annual/pdf/epa.pdf.	
Ash Disposal Cost ($/ton)	48.8	Waste Business Journal. The Cost to Landfill MSW Continues to Rise Despite Soft Demand. July 11, 2017. Available at: http://www.wastebusinessjournal.com/news/wbj20170711A.htm.	
Percent sulfur content for Coal (% weight)	1.84	Average sulfur content based on U.S. coal data for 2016 compiled by the U.S. Energy Information Administration (EIA) from data reported on EIA Form EIA-923, Power Plant Operations Report. Available at http://www.eia.gov/electricity/data/eia923/.	
Percent ash content for Coal (% weight)	9.23	Average ash content based on U.S. coal data for 2016 compiled by the U.S. Energy Information Administration (EIA) from data reported on EIA Form EIA-923, Power Plant Operations Report. Available at http://www.eia.gov/electricity/data/eia923/.	
Higher Heating Value (HHV	11,841	2016 coal data compiled by the Office of Oil, Gas, and Coal Supply Statistics, U.S. Energy Information Administration (EIA) from data reported on EIA Form EIA-923, Power Plant Operations Report. Available at http://www.eia.gov/electricity/data/eia923/.	
Interest Rate (%)	5.5	Default bank prime rate	

APPENDIX 13

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 Annual Heat Input Rate (Q_B) =	HHV x Max. Fuel Rate =	250	MMBtu/hour	
Maximum Annual fuel consumption (mfuel) =	(QB x 1.0E6 Btu/MMBtu x 8760)/HHV =	365,000,000	lbs/year	
Actual Annual fuel consumption (Mactual) =		365,000,000	lbs/year	
Heat Rate Factor (HRF) =	NPHR/10 =	1.00		
Total System Capacity Factor (CF_{total}) =	(Mactual/Mfuel) x (tSNCR/365) =	1.00	fraction	
Total operating time for the SNCR (t_{op}) =	CF_{total} x 8760 =	8760	hours	
NOx Removal Efficiency (EF) =	(NOx_{in} - NOx_{out})/NOx_{in} =	30	percent	
NOx removed per hour =	NOx_{in} x EF x Q_B =	12.00	lb/hour	
Total NO_x removed per year =	(NOx_{in} x EF x Q_B x t_{op})/2000 =	52.56	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)	1.07		
SO_2 Emission rate =	(%S/100)x(64/32)*($1x10^6$)/HHV =	> 3	lbs/MMBtu	
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 250 feet above sea level (P) =	2116x[(59-(0.00356xh)+459.7)/518.6]$^{5.256}$ x (1/144)* =	14.6	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.

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) = (whre SR = 1 for NH_3; 2 for Urea)	18	lb/hour
Reagent Usage Rate (m_{sol}) =	$m_{reagent}/C_{sol}$ =	62	lb/hour
	(m_{sol} x 7.4805)/Reagent Density =	8.3	gal/hour
Estimated tank volume for reagent storage =	(m_{sol} x 7.4805 x $t_{storage}$ x 24 hours/day)/Reagent Density =	2,800	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 = Where n = Equipment Life and i= Interest Rate	0.0688

Parameter	Equation	Calculated Value	Units
Electricity Usage: Electricity Consumption (P) =	(0.47 x NOx_{in} x NSR x Q_B)/NPHR =	2.3	kW/hour
Water Usage: Water consumption (q_w) =	(m_{sol}/Density of water) x ((C_{stored}/C_{inj}) - 1) =	14	gallons/hour
Fuel Data: Additional Fuel required to evaporate water in injected reagent (ΔFuel) =	Hv x $m_{reagent}$ x ((1/C_{inj})-1) =	0.15	MMBtu/hour
Ash Disposal: Additional ash produced due to increased fuel consumption (Δash) =	(Δfuel x %Ash x $1x10^6$)/HHV =	2.3	lb/hour

APPENDIX 13

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 ($SNCR_{cost}$) =	$682,343 in 2016 dollars
Air Pre-Heater Costs (APH_{cost})* =	$895,698 in 2016 dollars
Balance of Plant Costs (BOP_{cost}) =	$935,477 in 2016 dollars
Total Capital Investment (TCI) =	$3,267,573 in 2016 dollars

* This factor applies because the boiler burns bituminous coal and emits equal to or greater than 0.3lb/MMBtu of sulfur dioxide.

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 ($SNCR_{cost}$) =	$682,343 in 2016 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}) =	$895,698 in 2016 dollars

* This factor applies because the boiler burns bituminous coal and emits equal to or greater than 0.3lb/MMBtu of sulfur dioxide.

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}) =	$935,477 in 2016 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$75,802 in 2016 dollars
Indirect Annual Costs (IDAC) =	$226,279 in 2016 dollars
Total annual costs (TAC) = DAC + IDAC	$302,081 in 2016 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 =	$49,014 in 2016 dollars
Annual Reagent Cost =	$q_{sol} \times Cost_{reag} \times t_{op}$ =	$21,355 in 2016 dollars
Annual Electricity Cost =	$P \times Cost_{elect} \times t_{op}$ =	$1,358 in 2016 dollars
Annual Water Cost =	$q_{water} \times Cost_{water} \times t_{op}$ =	$518 in 2016 dollars
Additional Fuel Cost =	$\Delta Fuel \times Cost_{fuel} \times t_{op}$ =	$3,076 in 2016 dollars
Additional Ash Cost =	$\Delta Ash \times Cost_{ash} \times t_{op} \times (1/2000)$ =	$481 in 2016 dollars
Direct Annual Cost =		$75,802 in 2016 dollars

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0.03 x Annual Maintenance Cost =	$1,470 in 2016 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$224,809 in 2016 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$226,279 in 2016 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$302,081 per year in 2016 dollars
NOx Removed =	53 tons/year
Cost Effectiveness =	$5,747 per ton of NOx removed in 2016 dollars

APPENDIX 14

SCR Cost Analysis for CFB greater than 250 MMBtu/hr					
Control technology	Control efficiency	Uncontrolled emission level lb/Mmbtu	Size of boiler Mmbtu/hr	Cost per ton of NOx 2016	Cost per ton of NOx 2020
SCR	80%	0.16	250	$8,389	$9,060
SCR	80%	0.16	10000	$5,099	$5,507

SAMPLE CALCULATION

Data Inputs

Enter the following data for your combustion unit:

Is the combustion unit a utility or industrial boiler? Industrial

What type of fuel does the unit burn? Coal

Is the SCR for a new boiler or retrofit of an existing boiler? Retrofit

Please enter a retrofit factor between 0.8 and 1.5 based on the level of difficulty. Enter 1 for projects of average retrofit difficulty. 1

Complete all of the highlighted data fields:

What is the maximum heat input rate (QB)? 10,000 MMBtu/hour

What is the higher heating value (HHV) of 11,841 Btu/lb

*HHV value of 11841 Btu/lb is a default value. See below for data source. Enter actual HHV for fuel burned, if known.

What is the estimated actual annual fuel consumption? 7,398,023,816 lbs/year

Enter the net plant heat input rate (NPHR) 10 MMBtu/MW

If the NPHR is not known, use the default N

Fuel Type	Default NPHR
Coal	10 MMBtu/MW
Fuel Oil	11 MMBtu/MW
Natural Gas	8.2 MMBtu/MW

Plant Elevation 1500 Feet above sea level

Provide the following information for coal-fired boilers:

Type of coal burned: Bituminous

Enter the sulfur content (%S) = 1.00 percent by weight

For units burning coal blends:

Note: The table below is pre-populated with default values for HHV and %S. Please enter the actual values for these parameters in the table below. If the actual value for any parameter is not known, you may use the default values provided.

Coal Type	Fraction in Coal Blend	%S	HHV (Btu/lb)
Bituminous	0	1.84	11,841
Sub-Bituminous	0	0.41	8,826
Lignite	0	0.82	6,685

Please click the calculate button to calculate weighted average values based on the data in the table above.

For coal-fired boilers, you may use either Method 1 or Method 2 to calculate the catalyst replacement cost. The equations for both methods are shown on rows 85 and 86 on the ***Cost Estimate*** tab. Please select your preferred method:

- Method 1
- Method 2 (selected)
- Not applicable

Enter the following design parameters for the proposed SCR:

Number of days the SCR operates (t_{SCR}) 365 days

Number of days the boiler operates (t_{plant}) 365 days

Inlet NO_x Emissions (NOx_{in}) to SCR 0.16 lb/MMBtu

Outlet NO_x Emissions (NOx_{out}) from SCR 0.032 lb/MMBtu

Stoichiometric Ratio Factor (SRF) 0.525

*The SRF value of 0.525 is a default value. User should enter actual value, if known.

Estimated operating life of the catalyst (H_c 24,000 hours

Estimated SCR equipment life 30 Years*

* For industrial boilers, the typical equipment life is between 20 and 25 years.

Concentration of reagent as stored (C_{stored}) 50 percent*

Density of reagent as stored (ρ_{stored}) 71 lb/cubic feet*

Number of days reagent is stored ($t_{storage}$) 14 days

*The reagent concentration of 50% and density of 71 lbs/cft are default values for urea reagent. User should enter actual values for reagent, if different from the default values provided.

Select the reagent used: Urea

Number of SCR reactor chambers (n_{scr}) 1

Number of catalyst layers (R_{layer}) 3

Number of empty catalyst layers (R_{empty}) 1

Ammonia Slip (Slip) provided by vendor 2 ppm

Volume of the catalyst layers ($Vol_{catalyst}$) (Enter "UNK" if value is not known) UNK Cubic feet

Flue gas flow rate ($Q_{fluegas}$) (Enter "UNK" if value is not known) UNK acfm

Gas temperature at the SCR inlet (T) 650 °F

*The SCR inlet temperature of 650 deg.F is a default value.

Base case fuel gas volumetric flow rate factor (Q_{fuel}) 484 ft^3/min-MMBtu/hour

Densities of typical SCR reagents:	
50% urea solution	71 lbs/ft^3
29.4% aqueous NH_3	56 lbs/ft^3

Enter the cost data for the proposed SCR:

Desired dollar-year 2016

CEPCI for 2016 541.7 | 541.7 | 2016 CEPCI — CEPCI = Chemical Engineering Plant Cost Index

Annual Interest Rate (i) 5.5 Percent* — * 5.5 percent is the default bank prime rate. User should enter current bank prime rate (available at https://www.federalreserve.gov/releases/h15/.)

Reagent ($Cost_{reag}$) 1.660 $/gallon for 50% urea* — * $1.66/gallon is a default value for 50% urea. User should enter actual value, if known.

Electricity ($Cost_{elect}$) 0.0676 $/kWh — * $0.0676/kWh is a default value for electrity cost. User should enter actual value, if known.

Catalyst cost ($CC_{replace}$) 227.00 $/cubic foot (includes removal and disposal/regeneration of existing catalyst and installation of new catalyst — * $227/cf is a default value for the catalyst cost based on 2016 prices. User should enter actual value, if known.

Operator Labor Rate 60.00 $/hour (including benefits)* — * $60/hour is a default value for the operator labor rate. User should enter actual value, if known.

Operator Hours/Day 4.00 hours/day* — * 4 hours/day is a default value for the operator labor. User should enter actual value, if known.

Note: The use of CEPCI in this spreadsheet is not an endorsement of the index, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

Maintenance and Administrative Charges Cost Factors:

Maintenance Cost Factor (MCF) = 0.005

Administrative Charges Factor (ACF) = 0.03

Data Sources for Default Values Used in Calculations:

Data Element	Default Value	Sources for Default Value	If you used your own site-specific values, please enter the value used and the reference source . . .	Recommended data sources for site-specific
Reagent Cost ($/gallon)	$1.66/gallon 50% urea solution	U.S. Environmental Protection Agency (EPA). Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model, Updates to the Cost and Performance for APC Technologies, SCR Cost Development Methodology, Chapter 5, Attachment 5-3, January 2017. Available at: https://www.epa.gov/sites/production/files/2018-05/documents/attachment_5-3_scr_cost_development_methodology.pdf.		Check with reagent vendors for current prices.
Electricity Cost ($/kWh)	0.0676	U.S. Energy Information Administration. Electric Power Monthly. Table 5.3. Published December 2017. Available at: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a.		Plant's utility bill or use U.S. Energy Information Administration (EIA) data for most recent year.
Percent sulfur content for Coal (% weight)	1.84	Average sulfur content based on U.S. coal data for 2016 compiled by the U.S. Energy Information Administration (EIA) from data reported on EIA Form EIA-923, Power Plant Operations Report. Available at http://www.eia.gov/electricity/data/eia923/.		Check with fuel supplier or use U.S. Energy Information Administration (EIA) data for most
Higher Heating Value (HHV) (Btu/lb)	11,841	2016 coal data compiled by the Office of Oil, Gas, and Coal Supply Statistics, U.S. Energy Information Administration (EIA) from data reported on EIA Form EIA-923, Power Plant Operations Report. Available at http://www.eia.gov/electricity/data/eia923/.		Fuel supplier or use U.S. Energy Information Administration (EIA) data for most
Catalyst Cost ($/cubic foot)	227	U.S. Environmental Protection Agency (EPA). Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model. Office of Air and Radiation. May 2018. Available at: https://www.epa.gov/airmarkets/documentation-epas-power-sector-modeling-platform-v6.		Check with vendors for current prices.
Operator Labor Rate ($/hour)	$60.00	U.S. Environmental Protection Agency (EPA). Documentation for EPA's Power Sector Modeling Platform v6 Using the Integrated Planning Model. Office of Air and Radiation. May 2018. Available at: https://www.epa.gov/airmarkets/documentation-epas-power-sector-modeling-platform-v6.		Use payroll data, if available, or check current edition of the Bureau of Labor Statistics, National Occupational Employment and Wage Estimates – United States (https://www.bls.gov/oes/current/oes_nat.htm).
Interest Rate (Percent)	5.5	Default bank prime rate		Use known interest rate or use bank prime rate, available at https://www.federalreserve.gov/releases/h15/.

APPENDIX 14

Cost Estimate

Total Capital Investment (TCI)

TCI for Coal-Fired Boilers

For Coal-Fired Boilers:

$$TCI = 1.3 \times (SCR_{cost} + RPC + APHC + BPC)$$

Capital costs for the SCR (SCR_{cost}) =	$188,238,031	in 2016 dollars
Reagent Preparation Cost (RPC) =	$3,373,507	in 2016 dollars
Air Pre-Heater Costs (APHC)* =	$0	in 2016 dollars
Balance of Plant Costs (BPC) =	$10,157,840	in 2016 dollars
Total Capital Investment (TCI) =	$262,300,191	in 2016 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emits equal to or greater than 3lb/MMBtu of sulfur dioxide.

SCR Capital Costs (SCR_{cost})

For Coal-Fired Utility Boilers >25 MW:

$$SCR_{cost} = 310{,}000 \times (NRF)^{0.2} \times (B_{MW} \times HRF \times CoalF)^{0.92} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers >250 MMBtu/hour:

$$SCR_{cost} = 310{,}000 \times (NRF)^{0.2} \times (0.1 \times Q_B \times CoalF)^{0.92} \times ELEVF \times RF$$

SCR Capital Costs (SCR_{cost}) =	$188,238,031 in 2016 dollars

Reagent Preparation Costs (RPC)

For Coal-Fired Utility Boilers >25 MW:

$$RPC = 564{,}000 \times (NOx_{in} \times B_{MW} \times NPHR \times EF)^{0.25} \times RF$$

For Coal-Fired Industrial Boilers >250 MMBtu/hour:

$$RPC = 564{,}000 \times (NOx_{in} \times Q_B \times EF)^{0.25} \times RF$$

Reagent Preparation Costs (RPC) =	$3,373,507 in 2016 dollars

Air Pre-Heater Costs (APHC)*

For Coal-Fired Utility Boilers >25MW:

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

For Coal-Fired Industrial Boilers >250 MMBtu/hour:

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

Air Pre-Heater Costs (APH_{cost}) =	$0 in 2016 dollars

* Not applicable - This factor applies only to coal-fired boilers that burn bituminous coal and emit equal to or greater than 3lb/MMBtu of sulfur dioxide.

Balance of Plant Costs (BPC)

For Coal-Fired Utility Boilers >25MW:

$$BPC = 529{,}000 \times (B_{MW} \times HRFx\ CoalF)^{0.42} \times ELEVF \times RF$$

For Coal-Fired Industrial Boilers >250 MMBtu/hour:

$$BPC = 529{,}000 \times (0.1 \times Q_B \times CoalF)^{0.42}\ ELEVF \times RF$$

Balance of Plant Costs (BOP_{cost}) =	$10,157,840 in 2016 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$10,520,850 in 2016 dollars
Indirect Annual Costs (IDAC) =	$18,064,619 in 2016 dollars
Total annual costs (TAC) = DAC + IDAC	$28,585,469 in 2016 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 =	$1,311,501 in 2016 dollars
Annual Reagent Cost =	$m_{sol} \times Cost_{reag} \times t_{op}$ =	$2,687,923 in 2016 dollars
Annual Electricity Cost =	$P \times Cost_{elect} \times t_{op}$ =	$3,316,186 in 2016 dollars
Annual Catalyst Replacement Cost =		$3,205,240 in 2016 dollars

For coal-fired boilers, the following methods may be used to calcuate the catalyst replacement cost.

Method 1 (for all fuel types): $n_{scr} \times Vol_{cat} \times (CC_{replace}/R_{layer}) \times FWF$ — * Calculation Method 2 selected.

Method 2 (for coal-fired industrial boilers): $(Q_B/NPHR) \times 0.4 \times (CoalF)^{2.9} \times (NRF)^{0.71} \times (CC_{replace}) \times 35.3$

Direct Annual Cost =	$10,520,850 in 2016 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) =	$18,366 in 2016 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$18,046,253 in 2016 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$18,064,619 in 2016 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$28,585,469	per year in 2016 dollars
NOx Removed =	5,606	tons/year
Cost Effectiveness =	$5,099	per ton of NOx removed in 2016 dollars
Cost Effectiveness =	**$5,507**	**per ton of NOx removed in 2020 dollars**

APPENDIX 15

SCR Cost Analysis for other solid fuel-fired combustion unit greater than 50 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/Reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.25	0.25	
TOTAL CAPITAL COST (TCC) in 2016	$4,599,871	$12,972,142	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
TOTAL CAPITAL COST (TCC) in 2020	$5,013,859	$14,139,635	With CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Elecricity	$18,073.29	$90,366	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Chemical Cost (Urea/Ammonia)	$22,888.91	$114,447	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Catalyst Replacement (costs/No. of years)	$17,468.34	$87,343	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% ofmaintenance +labor
Property Taxes (1% of TCC-OAQPS)	$50,139	$141,396	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$50,139	$141,396	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$344,954	$972,807	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$611,935	$1,656,029	
Uncontrolled NOx TPY	54.75	273.75	
NOx removed TPY (80% Eff.)	44	219	
COST-EFFECTIVENSSS ($/Ton NOx removed)	$13,971	$7,562	

APPENDIX 16

SNCR Cost Analysis for other solid fuel-fired combustion unit greater than 50 MMBtu/hr			
Boiler Capacity MMBtu/hr	50	250	Factors/Reference used
Hrs/Yr	8760	8760	
NOx emissions (lb/MMBtu)	0.25	0.25	
TOTAL CAPITAL COST (TCC) in 2016	$1,706,180	$3,920,603	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
TOTAL CAPITAL COST (TCC) in 2020	$1,859,736	$4,273,457	With CPI 1.09 from 2016 to 2020
Direct Annual Costs			
Elecricity	$462.16	$2,313	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Water Cost	$380.41	$1,900	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Ash Cost	$146.06	$732	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Additional Fuel Cost	$1,847.55	$9,238	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material	$32,850	$32,850	100% of maintenance labor
Chemical Cost (Urea/Ammonia)	$33,243.91	$166,221	EPA spreadsheet for 50 and 250 mmbtu/hr boilers
Indirect Annual Costs			
Administration (3% of maintenance+labor)	$3,154	$3,154	3% of maintenance +labor
Property Taxes (1% of TCC-OAQPS)	$18,597	$42,735	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS)	$18,597	$42,735	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%)	$117,385	$269,737	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost)	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST	$298,934	$643,884	
Uncontrolled NOx TPY	54.75	273.75	
NOx removed TPY (30% Eff.)	16	82	
COST-EFFECTIVENESS ($/Ton NOx removed)	$18,200	$7,840	

APPENDIX 17

Cost Analysis for Oxidation Catalyst for combustion units and process heaters greater than 50 MMBtu/hr							
Boiler Size (MMBtu/hr)	30	50	100	150	200	250	Factors/References
TOTAL CAPITAL COST							
TOTAL CAPITAL COST (TCC)	$273,400	$455,667	$911,333	$1,367,000	$1,822,667	$2,278,333	
Catalyst Replacement	$26,000	$26,000	$26,000	$26,000	$26,000	$26,000	Company Estimate
Taxes, Insurance, Administration	$10,936	$18,227	$36,453	$54,680	$72,907	$91,133	4% of TEC
Capital Recovery (5.5% @ 20 yrs)	$22,884	$38,139	$76,279	$114,418	$152,557	$190,697	TCC*0.0837
TOTAL ANNUALIZED COST	$76,419	$82,366	$138,732	$195,098	$251,464	$307,830	
Uncontrolled VOC emissions (lb/MMBtu)	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	An average uncontrolled VOC emission rate
Uncontrolled VOC emissions (tons/year)	1.31	2.19	4.38	6.57	8.76	10.95	
VOC removed TPY (60% Eff.)	0.79	1.31	2.63	3.94	5.26	6.57	
COST-EFFECTIVENESS ($/Ton NOx removed)	$96,929.22	$62,683.38	$52,789.93	$49,492.11	$47,843.20	$46,853.86	

APPENDIX 18

Cost Analysis for SCR for NG-fired combined cycle turbines between 1000 and 60000 HP								
Turbine Horsepower (bhp)	HP		1000	3000	11150	15900	30000	60000
Operating Hours (h)	H		8760	8760	8760	8760	8760	8760
Fuel Consumption (MMBtu/h)	FC		10.99	21.99	80.17	117.58	190.80	309.10
TOTAL CAPITAL INVESTMENT (TCI)								
SCR Catalyst Housing and Control System	A	Based on vendors quote	$736,214.21	$845,553.61	$1,291,111.68	$1,550,792.76	$2,321,635.56	$3,961,726.60
Reductant Storage Tank	A'	Based on vendor's Quote	$19,763.93	$28,699.75	$65,113.22	$86,335.80	$149,333.33	$283,370.64
Total Purchased Equipment Costs	B	PA sales tax of 6% (1.06*(A+A'))	$801,336.83	$926,708.57	$1,437,598.40	$1,735,356.27	$2,619,227.02	$4,499,803.08
Direct Installation Costs	0.30B	OAQPS	$240,401.05	$278,012.57	$431,279.52	$520,606.88	$785,768.11	$1,349,940.92
Indirect Installation Costs	0.31B	OAQPS	$248,414.42	$287,279.66	$445,655.50	$537,960.44	$811,960.38	$1,394,938.96
Contingencies	0.24B	OAQPS 24% of equipment	$192,320.84	$222,410.06	$345,023.62	$416,485.51	$628,614.49	$1,079,952.74
Total Capital Costs	C	Sum(Row 8:Row 11)*1.11 (CPI)	$1,645,545.18	$1,902,996.04	$2,952,108.31	$3,563,554.11	$5,378,582.69	$9,240,345.63
Direct Annual Costs								
Power Costs		PC*H*PP	$940.74	$2,822.23	$8,872.44	$9,005.94	$14,614.11	$29,228.22
Reductant Costs		RC*H*RC	$5,598.25	$16,794.76	$52,814.87	$77,461.83	$125,698.71	$251,397.42
SCR Catalyst Replacement Costs		H/SCL*SCC	$6,569.79	$19,709.36	$54,532.38	$68,471.44	$90,531.72	$181,063.43
Replacement Parts		Vendor's quote	$4,976.13	$4,976.13	$4,976.13	$4,976.13	$4,976.13	$4,976.13
Operating Labor		OW*OH*SY	$11,804.10	$11,804.10	$11,804.10	$11,804.10	$11,804.10	$11,804.10
Maintenance Labor	D	MW*MH*SY	$6,493.35	$6,493.35	$6,493.35	$6,493.35	$6,493.35	$6,493.35
Total Direct Annual Costs	E	Sum(Row 15:Row 20)	$36,382.36	$62,599.93	$139,493.28	$178,212.79	$254,118.12	$484,962.65
Indirect Annual Costs								
Overhead	0.6D	OAQPS	$3,896.01	$3,896.01	$3,896.01	$3,896.01	$3,896.01	$3,896.01
Property Tax	0.02C	OAQPS using PA property tax of 2%	$14,724.28	$16,911.07	$25,822.23	$31,015.86	$46,432.71	$79,234.53
Insurance	0.01C	OAQPS	$7,362.14	$8,455.54	$12,911.12	$15,507.93	$23,216.36	$39,617.27
Administrative	0.02C	OAQPS	$14,724.28	$16,911.07	$25,822.23	$31,015.86	$46,432.71	$79,234.53
Capital Recovery		5.5% for 30 years=.0688	$113,213.51	$179,642.83	$278,679.02	$336,399.51	$507,738.21	$872,288.63
Total Indirect Annual Costs	F	Sum(Row 23:Row27)	$153,920.23	$225,816.52	$347,130.62	$417,835.16	$627,715.99	$1,074,270.97
TOTAL ANNUALIZED COST	G	E+F	$190,302.59	$288,416.44	$486,623.90	$596,047.95	$881,834.11	$1,559,233.62
Control Efficiency	CE		80%	80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	NER*FC*H	7.45	14.90	54.33	79.69	129.31	209.48
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	5.96	11.92	43.46	63.75	103.45	167.58
COST-EFFECTIVENESS ($/ton NOx removed)		G/NR	$31,928.71	$24,195.06	$11,195.82	$9,350.01	$8,524.61	$9,304.30
Assumptions:								
Power Consumption Rate (kW)	PC	Cost Manual Estimate (GP5A Turbine Ref sheet)	1.45	4.35	13.67	13.87	22.51	45.03
Industrial Retail Power Price ($/kWh)	PP	EIA Data		$0.0741				
Reductant Consumption Rate (gal/h)	RC	Cost Manual Estimate (GP5A Turbine Ref sheet)	0.256	0.767	2.412	3.537	5.740	11.479
Reductant Price ($/gal)	RP	Vendor quote (Ref-Reductant consumption price)		$2.50				
SCR Catalyst Cost ($)	SCC	Cost Manual Estimate (GP5A Turbine Ref sheet)	$14,999.51	$44,998.53	$124,503.16	$156,327.48	$206,693.42	$413,386.84
SCR Catalyst Life (h)	SCL	Vendor's quote		20,000				
Operator Wages ($/h)	OW	MSC quote (Ref-Reductant consumption price)		$21.56				
Operator Hours per Shift (h)	OH			0.50				
Shifts per Year	SY	3 shifts/day*365 days/year		1,095				
Maintenance Wages ($/h)	MW	MSC quote (Ref-Reductant consumption price)		$23.72				
Maintenance Hours per Shift	MH			0.25				
Interest Rate	IR			5.50%				
Equipment Life (y)	EL			30				
NOx Emission Rate (ppm)	N		4.20E-05	4.2E-05	4.2E-05	4.2E-05	4.2E-05	4.2E-05
Molar Volume @ 14.7 psi and 70 F (scf/lb-mol)	MV			386.80				
Molecular Weight of NO2 (lb/lb-mol)	MW			46.01				
Fuel Volume (scf/MMBtu)	FD	For 1050 Btu/scf Natural Gas @ 70 F		8,743				
Oxygen Content	OC			15%				
NOx Emission Rate (lb/MMBtu)	NER		0.1547	0.1547	0.1547	0.1547	0.1547	0.1547

APPENDIX 19

Cost Analysis for oxidation catalyst for combustion turbines rated between 1,000 - 60,000 Bhp				
	Cost	Costs	Costs	Costs
Uncontrolled NMNEC as propane (ppm @ 15% O2)	5	5	5	5
HP	1,000	15,900	30,000	60,000
MW	0.708215297	11.26062323	21.24645892	42.49291785
Hrs/Yr	8760	8760	8760	8760
Fuel Consumption (MMBtu/h)	10.99	117.58	190.8	309.1
NMNEHC Emission Rate (lb/MMBtu)	0.017659376	0.017659376	0.017659376	0.017659376
Total Uncontrolled NMNEHC emissions in Tons per Year	0.85	9.09	14.76	23.91
Total NMNEHC Removed in Tons per Year (60%)	0.51	5.46	8.85	14.34
TOTAL CAPITAL COST				
Oxidation Catalyst Purchased Equipment Costs	$96,785	$205,918	$215,090	$215,090
Direct Installation Costs (0.30PEC)	$29,035	$61,775	$64,527	$64,527
Total Indirect Installation Costs (0.27PEC)	$26,132	$55,598	$58,074	$58,074
Project Contingency (0.15(DIC+IIC))	$8,275	$17,606	$18,390	$18,390
Total Capital Investment	$160,227	$340,897	$356,082	$356,082
Direct Annual Costs				
Operating and Supervisory Labor Costs	$18,889	$18,889	$18,889	$18,889
Maintenance Cost	$2,904	$6,178	$6,453	$6,453
Natural Gas Penalty	$12,553	$28,325	$45,964	$45,964
Catalyst Disposal	$130	$338	$637	$637
Annual Catalyst Replacement Cost	$14,204	$36,841	$69,512	$69,512
Indirect Annual Costs				
Overhead (60% of Maintenance (EPA OAQPS)	$1,742	$3,707	$3,872	$3,872
PropertyTax+Ins.+Admn. (4% of TCI - OAQPS)	$6,409	$13,636	$14,243	$14,243
Capital Recovery (5.5% @ 20 yrs)	$13,411	$28,533	$29,804	$29,804
TOTAL ANNUALIZED COST	$70,242	$136,446	$189,373	$189,373
COST-EFFECTIVENESS ($/Ton NMNEHC removed)	$137,719.59	$25,004.91	$21,386.45	$13,201.34

APPENDIX 20

Cost Analysis for SCR for NG-fired simple cycle turbines between 1000 and 3000 HP				
Turbine Horsepower (bhp)	HP		1000	3000
Operating Hours (h)	H		8760	8760
Fuel Consumption (MMBtu/h)	FC		10.99	21.99
TOTAL CAPITAL INVESTMENT (TCI)				
SCR Catalyst Housing and Control System	A	Based on vendors quote	$2,629,336.46	$3,019,834.33
Reductant Storage Tank	A'	Based on vendor's Quote	$70,585.47	$102,499.12
Total Purchased Equipment Costs	B	PA sales tax of 6% (1.06*(A+A'))	$2,861,917.25	$3,309,673.46
Direct Installation Costs	0.30B	OAQPS	$858,575.18	$992,902.04
Indirect Installation Costs	0.31B	OAQPS	$887,194.35	$1,025,998.77
Contingencies	0.24B	OAQPS 24% of equipment	$686,860.14	$794,321.63
Total Capital Costs	C	Sum(Row 8:Row 11)*1.11 (CPI)	$5,876,947.08	$6,796,414.45
Direct Annual Costs				
Power Costs		PC*H*PP	$1,122.45	$3,367.36
Reductant Costs		RC*H*RC	$20,006.53	$60,019.58
SCR Catalyst Replacement Costs		H/SCL*SCC	$6,569.79	$19,709.36
Replacement Parts		Vendor's quote	$4,976.13	$4,976.13
Operating Labor		OW*OH*SY	$11,804.10	$11,804.10
Maintenance Labor	D	MW*MH*SY	$6,493.35	$6,493.35
Total Direct Annual Costs	E	Sum(Row 15:Row 20)	$50,972.34	$106,369.87
Indirect Annual Costs				
Overhead	0.6D	OAQPS	$3,896.01	$3,896.01
Property Tax	0.02C	OAQPS using PA property tax of 2%	$52,586.73	$60,396.69
Insurance	0.01C	OAQPS	$26,293.36	$30,198.34
Administrative	0.02C	OAQPS	$52,586.73	$60,396.69
Capital Recovery		5.5% for 30 years=.0688	$404,333.96	$641,581.52
Total Indirect Annual Costs	F	Sum(Row 23:Row27)	$539,696.79	$796,469.25
TOTAL ANNUALIZED COST	G	E+F	$590,669.13	$902,839.12
Control Efficiency	CE		80%	80%
Potential to Emit (TPY)	PTE	NER*FC*H	26.61	53.22
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	21.29	42.57
COST-EFFECTIVENESS ($/ton NOx removed)		G/NR	$27,748.47	$21,206.80
Assumptions:				
Power Consumption Rate (kW)	PC	Cost Manual Estimate (GP5A Turbine Ref sheet)	1.73	5.19
Industrial Retail Power Price ($/kWh)	PP	EIA Data		$0.0741
Reductant Consumption Rate (gal/h)	RC	Cost Manual Estimate (GP5A Turbine Ref sheet)	0.914	2.741
Reductant Price ($/gal)	RP	Vendor quote (Ref-Reductant consumption price)		$2.50
SCR Catalyst Cost ($)	SCC	Cost Manual Estimate (GP5A Turbine Ref sheet)	$14,999.51	$44,998.53
SCR Catalyst Life (h)	SCL	Vendor's quote		20,000
Operator Wages ($/h)	OW	MSC quote (Ref-Reductant consumption price)		$21.56
Operator Hours per Shift (h)	OH			0.50
Shifts per Year	SY	3 shifts/day*365 days/year		1,095
Maintenance Wages ($/h)	MW	MSC quote (Ref-Reductant consumption price)		$23.72
Maintenance Hours per Shift	MH			0.25
Interest Rate	IR			5.50%
Equipment Life (y)	EL			30
NOx Emission Rate (ppm)	N		1.50E-04	1.5E-04
Molar Volume @ 14.7 psi and 70 F (scf/lb-mol)	MV			386.80
Molecular Weight of NO2 (lb/lb-mol)	MW			46.01
Fuel Volume (scf/MMBtu)	FD	For 1050 Btu/scf Natural Gas @ 70 F		8,743
Oxygen Content	OC			15%
NOx Emission Rate (lb/MMBtu)	NER		0.5526	0.5526

APPENDIX 21

Cost Analysis for oxidation catalyst for combustion turbines between 1000 - 3000 BHP			
	Cost	Costs	Costs
Uncontrolled NMNEC as propane (ppm @ 15% O2)	9	9	9
HP	1,000	1,500	3,000
MW	0.708215297	1.062322946	2.124645892
Hrs/Yr	8760	8760	8760
Heat Input (MMBtu/h)	11.06	16.59	33.1
NMNEHC Emission Rate (lb/MMBtu)	0.031786877	0.031786877	0.031786877
Total Uncontrolled NMNEHC emissions in Tons per Year	1.54	2.31	4.61
Total NMNEHC Removed in Tons per Year (60%)	0.92	1.39	2.77
TOTAL CAPITAL COST			
Oxidation Catalyst Purchased Equipment Costs	$96,785	$205,918	$215,090
Direct Installation Costs (0.30PEC)	$29,035	$61,775	$64,527
Total Indirect Installation Costs (0.27PEC)	$26,132	$55,598	$58,074
Project Contingency (0.15(DIC+IIC))	$8,275	$17,606	$18,390
Total Capital Investment	$160,227	$340,897	$356,082
Direct Annual Costs			
Operating and Supervisory Labor Costs	$18,889	$18,889	$18,889
Maintenance Cost	$2,904	$6,178	$6,453
Natural Gas Penalty	$12,553	$28,325	$45,964
Catalyst Disposal	$130	$338	$637
Annual Catalyst Replacement Cost	$14,204	$36,841	$69,512
Indirect Annual Costs			
Overhead (60% of Maintenance - EPA's OAQPS)	$1,742	$3,707	$3,872
PropertyTax+Ins.+Admn. (4% of TCI - EPA OAQPS)	$6,409	$13,636	$14,243
Capital Recovery (5.5% @ 20 yrs)	$13,411	$28,533	$29,804
Direct Annual Costs	$48,679	$90,570	$141,454
Indirect Annual Costs	$21,562	$45,875	$47,919
TOTAL ANNUALIZED COST	$70,242	$136,446	$189,373
COST-EFFECTIVENESS ($/Ton NMNEHC removed)	$76,026.63	$98,455.46	$68,488.34

APPENDIX 22

Cost Analysis for SCR for NG-fired simple cycle turbines between 3000 and 60000 HP							
Turbine Horsepower (bhp)	HP		3000	11150	15900	30000	60000
Operating Hours (h)	H		8760	8760	8760	8760	8760
Fuel Consumption (MMBtu/h)	FC		21.99	80.17	117.58	190.80	309.10
TOTAL CAPITAL INVESTMENT (TCI)							
SCR Catalyst Housing and Control System	A	Based on vendors quote	$845,553.61	$1,291,111.68	$1,550,792.76	$2,321,635.56	$3,961,726.60
Reductant Storage Tank	A'	Based on vendor's Quote	$28,699.75	$65,113.22	$86,335.80	$149,333.33	$283,370.64
Total Purchased Equipment Costs	B	PA sales tax of 6% (1.06*(A+A'))	$926,708.57	$1,437,598.40	$1,735,356.27	$2,619,227.02	$4,499,803.08
Direct Installation Costs	0.30B	OAQPS	$278,012.57	$431,279.52	$520,606.88	$785,768.11	$1,349,940.92
Indirect Installation Costs	0.31B	OAQPS	$287,279.66	$445,655.50	$537,960.44	$811,960.38	$1,394,938.96
Contingencies	0.24B	OAQPS 24% of equipment	$222,410.06	$345,023.62	$416,485.51	$628,614.49	$1,079,952.74
Total Capital Costs	C	Sum(Row 8:Row 11)*1.11 (CPI)	$1,902,996.04	$2,952,108.31	$3,563,554.11	$5,378,582.69	$9,240,345.63
Direct Annual Costs							
Power Costs		PC*H*PP	$2,822.23	$8,872.44	$9,005.94	$14,614.11	$29,228.22
Reductant Costs		RC*H*RC	$16,794.76	$52,814.87	$77,461.83	$125,698.71	$251,397.42
SCR Catalyst Replacement Costs		H/SCL*SCC	$19,709.36	$54,532.38	$68,471.44	$90,531.72	$181,063.43
Replacement Parts		Vendor's quote	$4,976.13	$4,976.13	$4,976.13	$4,976.13	$4,976.13
Operating Labor		OW*OH*SY	$11,804.10	$11,804.10	$11,804.10	$11,804.10	$11,804.10
Maintenance Labor	D	MW*MH*SY	$6,493.35	$6,493.35	$6,493.35	$6,493.35	$6,493.35
Total Direct Annual Costs	E	Sum(Row 15:Row 20)	$62,599.93	$139,493.28	$178,212.79	$254,118.12	$484,962.65
Indirect Annual Costs							
Overhead	0.6D	OAQPS	$3,896.01	$3,896.01	$3,896.01	$3,896.01	$3,896.01
Property Tax	0.02C	OAQPS using PA property tax of 2%	$16,911.07	$25,822.23	$31,015.86	$46,432.71	$79,234.53
Insurance	0.01C	OAQPS	$8,455.54	$12,911.12	$15,507.93	$23,216.36	$39,617.27
Administrative	0.02C	OAQPS	$16,911.07	$25,822.23	$31,015.86	$46,432.71	$79,234.53
Capital Recovery		5.5% for 30 years=.0688	$179,642.83	$278,679.02	$336,399.51	$507,738.21	$872,288.63
Total Indirect Annual Costs	F	Sum(Row 23:Row27)	$225,816.52	$347,130.62	$417,835.16	$627,715.99	$1,074,270.97
TOTAL ANNUALIZED COST	G	E+F	$288,416.44	$486,623.90	$596,047.95	$881,834.11	$1,559,233.62
Control Efficiency	CE		80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	NER*FC*H	14.90	54.33	79.69	129.31	209.48
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	11.92	43.46	63.75	103.45	167.58
COST-EFFECTIVENESS ($/ton NOx removed)		G/NR	$24,195.06	$11,195.82	$9,350.01	$8,524.61	$9,304.30
Assumptions:							
Power Consumption Rate (kW)	PC	Cost Manual Estimate (GP5A Turbine Ref sheet)	4.35	13.67	13.87	22.51	45.03
Industrial Retail Power Price ($/kWh)	PP	EIA Data	$0.0741				
Reductant Consumption Rate (gal/h)	RC	Cost Manual Estimate (GP5A Turbine Ref sheet)	0.767	2.412	3.537	5.740	11.479
Reductant Price ($/gal)	RP	Vendor quote (Ref-Reductant consumption price)	$2.50				
SCR Catalyst Cost ($)	SCC	Cost Manual Estimate (GP5A Turbine Ref sheet)	$44,998.53	$124,503.16	$156,327.48	$206,693.42	$413,386.84
SCR Catalyst Life (h)	SCL	Vendor's quote	20,000				
Operator Wages ($/h)	OW	MSC quote (Ref-Reductant consumption price)	$21.56				
Operator Hours per Shift (h)	OH		0.50				
Shifts per Year	SY	3 shifts/day*365 days/year	1,095				
Maintenance Wages ($/h)	MW	MSC quote (Ref-Reductant consumption price)	$23.72				
Maintenance Hours per Shift	MH		0.25				
Interest Rate	IR		5.50%				
Equipment Life (y)	EL		30				
NOx Emission Rate (ppm)	N		4.2E-05	4.2E-05	4.2E-05	4.2E-05	4.2E-05
Molar Volume @ 14.7 psi and 70 F (scf/lb-mol)	MV		386.80				
Molecular Weight of NO2 (lb/lb-mol)	MW		46.01				
Fuel Volume (scf/MMBtu)	FD	For 1050 Btu/scf Natural Gas @ 70 F	8,743				
Oxygen Content	OC		15%				
NOx Emission Rate (lb/MMBtu)	NER		0.1547	0.1547	0.1547	0.1547	0.1547

APPENDIX 23

Cost Analysis for SCR for Oil-fired simple cycle turbines between 3000 and 60000 HP							
Turbine Horsepower (bhp)	HP		3000	11150	15900	30000	60000
Operating Hours (h)	H		8760	8760	8760	8760	8760
Fuel Consumption (MMBtu/h)	FC		21.99	80.17	117.58	190.80	309.10
TOTAL CAPITAL INVESTMENT (TCI)							
SCR Catalyst Housing and Control System	A	Based on vendors quote	$1,932,693.97	$2,951,112.41	$3,544,669.17	$5,306,595.56	$9,055,375.09
Reductant Storage Tank	A'	Based on vendor's Quote	$65,599.44	$148,830.22	$197,338.97	$341,333.33	$647,704.33
Total Purchased Equipment Costs	B	PA sales tax of 6% (1.06*(A+A'))	$2,118,191.01	$3,285,939.19	$3,966,528.63	$5,986,804.62	$10,285,264.19
Direct Installation Costs	0.30B	OAQPS	$635,457.30	$985,781.76	$1,189,958.59	$1,796,041.39	$3,085,579.26
Indirect Installation Costs	0.31B	OAQPS	$656,639.21	$1,018,641.15	$1,229,623.87	$1,855,909.43	$3,188,431.90
Contingencies	0.24B	OAQPS 24% of equipment	$508,365.84	$788,625.41	$951,966.87	$1,436,833.11	$2,468,463.41
Total Capital Costs	C	Sum(Row 8:Row 11)*1.11 (CPI)	$4,349,705.25	$6,747,676.14	$8,145,266.53	$12,293,903.29	$21,120,790.01
Direct Annual Costs							
Power Costs		PC*H*PP	$3,097.33	$9,742.04	$10,281.36	$16,683.75	$33,367.49
Reductant Costs		RC*H*RC	$38,369.66	$120,719.70	$177,055.61	$287,311.34	$574,622.68
SCR Catalyst Replacement Costs		H/SCL*SCC	$19,709.36	$54,532.38	$68,471.44	$90,531.72	$181,063.43
Replacement Parts		Vendor's quote	$4,976.13	$4,976.13	$4,976.13	$4,976.13	$4,976.13
Operating Labor		OW*OH*SY	$11,804.10	$11,804.10	$11,804.10	$11,804.10	$11,804.10
Maintenance Labor	D	MW*MH*SY	$6,493.35	$6,493.35	$6,493.35	$6,493.35	$6,493.35
Total Direct Annual Costs	E	Sum(Row 15:Row 20)	$84,449.93	$208,267.71	$279,081.99	$417,800.38	$812,327.18
Indirect Annual Costs							
Overhead	0.6D	OAQPS	$3,896.01	$3,896.01	$3,896.01	$3,896.01	$3,896.01
Property Tax	0.02C	OAQPS using PA property tax of 2%	$38,653.88	$59,022.25	$70,893.38	$106,131.91	$181,107.50
Insurance	0.01C	OAQPS	$19,326.94	$29,511.12	$35,446.69	$53,065.96	$90,553.75
Administrative	0.02C	OAQPS	$38,653.88	$59,022.25	$70,893.38	$106,131.91	$181,107.50
Capital Recovery		5.5% for 30 years=.0688	$410,612.18	$636,980.63	$768,913.16	$1,160,544.47	$1,993,802.58
Total Indirect Annual Costs	F	Sum(Row 23:Row27)	$511,142.88	$788,432.26	$950,042.63	$1,429,770.26	$2,450,467.34
TOTAL ANNUALIZED COST	G	E+F	$595,592.81	$996,699.97	$1,229,124.62	$1,847,570.64	$3,262,794.52
Control Efficiency	CE		80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	NER*FC*H	34.06	124.19	182.14	295.56	478.81
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	27.25	99.35	145.71	236.45	383.04
COST-EFFECTIVENESS ($/ton NOx removed)		G/NR	$21,859.20	$10,032.40	$8,435.38	$7,813.88	$8,518.06
Assumptions:							
Power Consumption Rate (kW)	PC	Cost Manual Estimate (GP5A Turbine Ref sheet)	4.772	15.008	15.839	25.702	51.40
Industrial Retail Power Price ($/kWh)	PP	EIA Data	$0.0741				
Reductant Consumption Rate (gal/h)	RC	Cost Manual Estimate (GP5A Turbine Ref sheet)	1.752	5.512	8.085	13.119	26.238
Reductant Price ($/gal)	RP	Vendor quote (Ref-Reductant consumption price)	$2.50				
SCR Catalyst Cost ($)	SCC	Cost Manual Estimate (GP5A Turbine Ref sheet)	$44,998.53	$124,503.16	$156,327.48	$206,693.42	$413,386.84
SCR Catalyst Life (h)	SCL	Vendor's quote	20,000				
Operator Wages ($/h)	OW	MSC quote (Ref-Reductant consumption price)	$21.56				
Operator Hours per Shift (h)	OH		0.50				
Shifts per Year	SY	3 shifts/day*365 days/year	1,095				
Maintenance Wages ($/h)	MW	MSC quote (Ref-Reductant consumption price)	$23.72				
Maintenance Hours per Shift	MH		0.25				
Interest Rate	IR		5.50%				
Equipment Life (y)	EL		30				
NOx Emission Rate (ppm)	N		9.6E-05	9.6E-05	9.6E-05	9.6E-05	9.6E-05
Molar Volume @ 14.7 psi and 70 F (scf/lb-mol)	MV		386.80				
Molecular Weight of NO2 (lb/lb-mol)	MW		46.01				
Fuel Volume (scf/MMBtu)	FD	For 1050 Btu/scf Natural Gas @ 70 F	8,743				
Oxygen Content	OC		15%				
NOx Emission Rate (lb/MMBtu)	NER		0.3537	0.3537	0.3537	0.3537	0.3537

APPENDIX 24

Cost Analysis for SCR for natural gas-fired lean-burn engines between 500 - 3,500 BHP										
Engine Horsepower (bhp)	HP		500	1000	1380	1500	2000	2400	2500	3000
Operating Hours (h)	H		8760	8760	8760	8760	8760	8760	8760	8760
SCR Catalyst Housing and Control System	A	OAQPS	$232,597.34	$279,869.71	$315,796.70	$327,142.07	$374,414.44	$412,232.33	$421,686.80	$468,959.16
Reductant Storage Tank	A'	Vendor's quote	$6,014.80	$8,844.80	$10,995.60	$11,674.80	$14,504.80	$16,768.80	$17,334.80	$20,164.80
Total Purchased Equipment Costs	B	OAQPS with PA sales tax of 6%	$252,928.87	$306,037.38	$346,399.84	$359,145.88	$412,254.39	$454,741.19	$487,313.98	$542,927.60
Direct Installation Costs	0.30B	OAQPS	$75,878.66	$91,811.21	$103,919.95	$107,743.77	$123,676.32	$136,422.36	$146,194.19	$162,878.28
Indirect Installation Costs	0.31B	OAQPS	$78,407.95	$94,871.59	$107,383.95	$111,335.22	$127,798.86	$140,969.77	$151,067.33	$168,307.56
Contingencies	0.24B	OAQPS (0.15*(B+0.30B+0.31B))	$60,702.93	$73,448.97	$83,135.96	$86,195.01	$98,941.05	$109,137.89	$116,955.35	$130,302.62
TOTAL CAPITAL COST (TCC)	C	SUM ROW 7 - 10 with CPI	$519,389.44	$628,447.76	$711,332.08	$737,506.07	$846,564.39	$933,811.04	$1,000,699.25	$1,114,901.82
Direct Annual Costs										
Power Costs		PC*H*PP	$1,867.89	$2,481.09	$2,947.12	$3,094.28	$3,707.48	$4,198.04	$4,320.68	$4,933.88
Reductant Costs		RC*H*RC	$14,067.54	$28,135.07	$38,826.40	$42,202.61	$56,270.15	$67,524.17	$70,337.68	$84,405.22
SCR Catalyst Replacement Costs		H/SCL*SCC*1.11	$8,986.76	$9,751.08	$10,331.97	$10,515.41	$11,279.73	$11,891.19	$12,044.06	$12,808.38
Operating Labor plus 15% for Supervisor		OW*OH*SY*1.15	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72
Maintenance Labor plus Materials	D	MW*MH*SY*2	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70
Total Direct Annual Costs	E	Sum(Row 12:Row17)	$51,483.60	$66,928.66	$78,666.90	$82,373.72	$97,818.77	$110,174.82	$113,263.83	$128,708.89
Indirect Annual Costs										
Overhead	0.6D	OAQPS	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02
Property Tax	0.02C	OAQPS using PA property tax of 2%	$10,387.79	$12,568.96	$14,226.64	$14,750.12	$16,931.29	$18,676.22	$20,013.98	$22,298.04
Insurance	0.01C	OAQPS	$5,193.89	$6,284.48	$7,113.32	$7,375.06	$8,465.64	$9,338.11	$10,006.99	$11,149.02
Administrative	0.02C	OAQPS	$10,387.79	$12,568.96	$14,226.64	$14,750.12	$16,931.29	$18,676.22	$20,013.98	$22,298.04
Capital Recovery (5.5% @ 30 yrs)			$35,733.99	$43,237.21	$48,939.65	$50,740.42	$58,243.63	$64,246.20	$68,853.50	$76,711.25
Total Indirect Annual Costs	F	Sum(Row 20:Row24)	$69,495.49	$82,451.61	$92,298.27	$95,407.74	$108,363.87	$118,728.77	$126,680.48	$140,248.37
TOTAL ANNUALIZED COST	G	E+F	$120,979.09	$149,380.27	$170,965.17	$177,781.46	$206,182.64	$228,903.59	$239,944.32	$268,957.26
Control Efficiency	CE		80%	80%	80%	80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	ER*HP*H/(454 g/lb*2000 lb/ton)	14.47	28.94	39.94	43.41	57.89	69.46	72.36	86.83
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	11.58	23.15	31.95	34.73	46.31	55.57	57.89	69.46
COST EFFECTIVENESS ($/Ton of NOx removed)		G/NR	$10,449.87	$6,451.55	$5,350.56	$5,118.77	$4,452.38	$4,119.19	$4,145.16	$3,871.97
Assumptions:										
Power Consumption Rate (kW)	PC	OAQPS	2.88	3.82	4.54	4.77	5.71	6.47	6.66	7.60
Industrial Retail Power Price ($/kWh)	PP	EIA Data	$0.0741	$0.0741	$0.0741	$0.0741	$0.0741	$0.0741		
Reductant Consumption Rate (gal/h)	RC	OAQPS	0.642	1.285	1.773	1.927	2.569	3.083	3.212	3.854
Reductant Price ($/gal)	RP	Vendor's quote			$2.50					
SCR Catalyst Cost ($)	SCC	OAQPS	$18,484.43	$20,056.53	$21,251.33	$21,628.63	$23,200.73	$24,458.41	$24,772.83	$26,344.94
SCR Catalyst Life (h)	SCL	Vendor's quote			20,000					
Operator Wages ($/h)	OW	MSC quote ($21.56/hr)			$21.56					
Operator Hours per Shift (h)	OH				0.50					
Shifts per Year	SY	3 shifts/day*365 days/year			1,095					
Maintenance Wages ($/h)	MW	MSC quote			$23.72					
Maintenance Hours per Shift	MH				0.25					
Interest Rate	IR				5.50%					
Equipment Life (y)	EL				30					
NOx Emission Rate (g/bhp-h)	NER	Uncontrolled NOx Emissions >500 bhp			3.0					

APPENDIX 25

Cost Analysis for SCR for natural gas-fired lean-burn engines rated at Greater than 3500 BHP							
Engine Horsepower (bhp)	HP		3500	4000	4500	4735	5000
Operating Hours (h)	H		8760	8760	8760	8760	8760
SCR Catalyst Housing and Control System	A	OAQPS	$516,231.53	$563,503.89	$610,776.25	$632,994.26	$658,048.62
Reductant Storage Tank	A'	Vendor's quote	$22,994.80	$25,824.80	$28,654.80	$29,984.90	$31,484.80
Total Purchased Equipment Costs	B	OAQPS with PA sales tax of 6%	$598,541.22	$654,154.85	$709,768.47	$735,906.87	$765,382.09
Direct Installation Costs	0.30B	OAQPS	$179,562.37	$196,246.45	$212,930.54	$220,772.06	$229,614.63
Indirect Installation Costs	0.31B	OAQPS	$185,547.78	$202,788.00	$220,028.23	$228,131.13	$237,268.45
Contingencies	0.24B	OAQPS (0.15*(B+0.30B+0.31B))	$143,649.89	$156,997.16	$170,344.43	$176,617.65	$183,691.70
TOTAL CAPITAL COST (TCC)	C	SUM ROW 7 - 10 with CPI	$1,229,104.40	$1,343,306.98	$1,457,509.55	$1,511,184.76	$1,571,712.13
Direct Annual Costs							
Power Costs		PC*H*PP	$5,547.07	$6,160.27	$6,773.47	$7,061.67	$7,386.66
Reductant Costs		RC*H*RC	$98,472.75	$112,540.29	$126,607.83	$133,219.57	$140,675.36
SCR Catalyst Replacement Costs		H/SCL*SCC*1.11	$13,572.71	$14,337.03	$15,101.35	$15,460.59	$15,865.68
Operating Labor plus 15% for Supervisor		OW*OH*SY*1.15	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72
Maintenance Labor plus Materials	D	MW*MH*SY*2	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70
Total Direct Annual Costs	E	Sum(Row 12:Row17)	$144,153.95	$159,599.00	$175,044.06	$182,303.24	$190,489.12
Indirect Annual Costs							
Overhead	0.6D	OAQPS	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02
Property Tax	0.02C	OAQPS using PA property tax of 2%	$24,582.09	$26,866.14	$29,150.19	$30,223.70	$31,434.24
Insurance	0.01C	OAQPS	$12,291.04	$13,433.07	$14,575.10	$15,111.85	$15,717.12
Administrative	0.02C	OAQPS	$24,582.09	$26,866.14	$29,150.19	$30,223.70	$31,434.24
Capital Recovery (5.5% @ 30 yrs)			$84,569.01	$92,426.76	$100,284.51	$103,977.66	$108,142.27
Total Indirect Annual Costs	F	Sum(Row 20:Row24)	$153,816.25	$167,384.13	$180,952.01	$187,328.91	$194,519.89
TOTAL ANNUALIZED COST	G	E+F	$297,970.19	$326,983.13	$355,996.07	$369,632.15	$385,009.01
Control Efficiency	CE		80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	ER*HP*H/(454 g/lb*2000 lb/ton)	101.30	115.77	130.24	137.04	144.71
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	81.04	92.62	104.19	109.64	115.77
COST EFFECTIVENESS ($/Ton of NOx removed)		G/NR	$3,676.84	$3,530.50	$3,417	$3,371	$3,326
Assumptions:							
Power Consumption Rate (kW)	PC	OAQPS	8.55	9.49	10.43	10.88	11.38
Industrial Retail Power Price ($/kWh)	PP	EIA Data					
Reductant Consumption Rate (gal/h)	RC	OAQPS	4.496	5.139	5.781	6.083	6.424
Reductant Price ($/gal)	RP	Vendor's quote					
SCR Catalyst Cost ($)	SCC	OAQPS	$27,917.04	$29,489.14	$31,061.24	$31,800.13	$32,633.34
SCR Catalyst Life (h)	SCL	Vendor's quote					
Operator Wages ($/h)	OW	MSC quote ($21.56/hr)					
Operator Hours per Shift (h)	OH						
Shifts per Year	SY	3 shifts/day*365 days/year					
Maintenance Wages ($/h)	MW	MSC quote					
Maintenance Hours per Shift	MH						
Interest Rate	IR						
Equipment Life (y)	EL						
NOx Emission Rate (g/bhp-h)	NER	Uncontrolled NOx Emissions >500 bhp					

APPENDIX 26

Cost Analysis for SCR for oil-fired engines greater than 500 BHP															
Engine Horsepower (bhp)	HP		500	1000	1380	1500	2000	2400	2500	3000	3500	4000	4500	4735	5000
Operating Hours (h)	H		8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760	8760
SCR Catalyst Housing and Control System	A	OAQPS	$160,950.00	$321,900.00	$444,222.00	$482,850.00	$643,800.00	$772,560.00	$804,750.00	$965,700.00	$1,126,650.00	$1,287,600.00	$1,448,550.00	$1,524,196.50	$1,609,500.00
Reductant Storage Tank	A'	Vendor's quote	$6,014.80	$8,844.80	$10,995.60	$11,674.80	$14,504.80	$16,768.80	$17,334.80	$20,164.80	$22,994.80	$25,824.80	$28,654.80	$29,984.90	$31,484.80
Total Purchased Equipment Costs	B	OAQPS with PA sales tax of 6%	$176,982.69	$350,589.49	$482,530.66	$524,196.29	$697,803.09	$836,688.53	$912,514.13	$1,094,309.93	$1,276,105.73	$1,457,901.53	$1,639,697.33	$1,725,141.35	$1,821,493.13
Direct Installation Costs	0.30B	OAQPS	$53,094.81	$105,176.85	$144,759.20	$157,258.89	$209,340.93	$251,006.56	$273,754.24	$328,292.98	$382,831.72	$437,370.46	$491,909.20	$517,542.41	$546,447.94
Indirect Installation Costs	0.31B	OAQPS	$54,864.63	$108,682.74	$149,584.50	$162,500.85	$216,318.96	$259,373.44	$282,879.38	$339,236.08	$395,592.78	$451,949.47	$508,306.17	$534,793.82	$564,662.87
Contingencies	0.24B	OAQPS (0.15*(B+0.30B+0.31B))	$42,475.85	$84,141.48	$115,807.36	$125,807.11	$167,472.74	$200,805.25	$219,003.39	$262,634.38	$306,265.37	$349,896.37	$393,527.36	$414,033.92	$437,158.35
TOTAL CAPITAL COST (TCC)	C	SUM ROW 7 - 10 with CPI	$363,433.95	$719,935.51	$990,876.70	$1,076,437.08	$1,432,938.64	$1,718,139.89	$1,873,847.76	$2,247,165.44	$2,620,483.11	$2,993,800.79	$3,367,118.46	$3,542,577.77	$3,740,436.14
Direct Annual Costs															
Power Costs		PC*H*PP	$993.15	$1,986.29	$2,741.09	$2,979.44	$3,972.59	$4,767.11	$4,965.74	$5,958.88	$6,952.03	$7,945.18	$8,938.33	$9,405.11	$9,931.47
Reductant Costs		RC*H*RC	$27,243.60	$54,487.20	$75,192.34	$81,730.80	$108,974.40	$130,769.28	$136,218.00	$163,461.60	$190,705.20	$217,948.80	$245,192.40	$257,996.89	$272,436.00
SCR Catalyst Replacement Costs		H/SCL*SCC*1.11	$2,390.06	$4,780.12	$6,596.57	$7,170.18	$9,560.24	$11,472.29	$11,950.30	$14,340.37	$16,730.43	$19,120.49	$21,510.55	$22,633.88	$23,900.61
Operating Labor plus 15% for Supervisor		OW*OH*SY*1.15	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72	$13,574.72
Maintenance Labor plus Materials	D	MW*MH*SY*2	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70	$12,986.70
Total Direct Annual Costs	E	Sum(Row 12:Row17)	$57,188.22	$87,815.03	$111,091.41	$118,441.84	$149,068.65	$173,570.10	$179,695.46	$210,322.27	$240,949.07	$271,575.88	$302,202.69	$316,597.29	$332,829.50
Indirect Annual Costs															
Overhead	0.6D	OAQPS	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02	$7,792.02
Property Tax	0.02C	OAQPS using PA property tax of 2%	$7,268.68	$14,398.71	$19,817.53	$21,528.74	$28,658.77	$34,362.80	$37,476.96	$44,943.31	$52,409.66	$59,876.02	$67,342.37	$70,851.56	$74,808.72
Insurance	0.01C	OAQPS	$3,634.34	$7,199.36	$9,908.77	$10,764.37	$14,329.39	$17,181.40	$18,738.48	$22,471.65	$26,204.83	$29,938.01	$33,671.18	$35,425.78	$37,404.36
Administrative	0.02C	OAQPS	$7,268.68	$14,398.71	$19,817.53	$21,528.74	$28,658.77	$34,362.80	$37,476.96	$44,943.31	$52,409.66	$59,876.02	$67,342.37	$70,851.56	$74,808.72
Capital Recovery (5.5% @ 30 yrs)			$25,004.26	$49,531.56	$68,172.32	$74,058.87	$98,586.18	$118,208.02	$128,930.83	$154,617.09	$180,303.36	$205,989.63	$231,675.90	$243,748.44	$257,362.17
Total Indirect Annual Costs	F	Sum(Row 20:Row24)	$50,967.97	$93,320.36	$125,508.17	$135,672.74	$178,025.13	$211,907.04	$230,415.23	$274,767.39	$319,119.54	$363,471.69	$407,823.84	$428,669.35	$452,175.99
TOTAL ANNUALIZED COST	G	E+F	$108,156.20	$181,135.39	$236,599.58	$254,114.58	$327,093.78	$385,477.13	$410,110.69	$485,089.65	$560,068.61	$635,047.57	$710,026.53	$745,266.64	$785,005.49
Control Efficiency	CE		80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
Potential to Emit (TPY)	PTE	ER*HP*H/(454 g/lb*2000 lb/ton)	38.59	77.18	106.51	115.77	154.36	185.23	192.95	231.54	270.13	308.72	347.31	365.45	385.90
Annual Estimated NOx Removal (TPY)	NR	PTE*CE	30.87	61.74	85.21	92.62	123.49	148.19	154.36	185.23	216.11	246.98	277.85	292.36	308.72
COST EFFECTIVENESS ($/Ton of NOx removed)		G/NR	$3,503.35	$2,933.63	$2,776.75	$2,743.72	$2,648.77	$2,601.29	$2,656.82	$2,618.80	$2,591.64	$2,571.27	$2,555	$2,549	$2,543
Assumptions:															
Power Consumption Rate (kW)	PC	OAQPS	1.53	3.06	4.22	4.59	6.12	7.34	7.65	9.18	10.71	12.24	13.77	14.49	15.30
Industrial Retail Power Price ($/kWh)	PP	EIA Data	$0.0741	$0.0741	$0.0741	$0.0741	$0.0741	$0.0741							
Reductant Consumption Rate (gal/h)	RC	OAQPS	1.244	2.488	3.433	3.732	4.976	5.971	6.220	7.464	8.708	9.952	11.196	11.781	12.440
Reductant Price ($/gal)	RP	Vendor's quote			$2.50										
SCR Catalyst Cost ($)	SCC	OAQPS	$4,916.00	$9,832.00	$13,568.16	$14,748.00	$19,664.00	$23,596.80	$24,580.00	$29,496.00	$34,412.00	$39,328.00	$44,244.00	$46,554.52	$49,160.00
SCR Catalyst Life (h)	SCL	Vendor's quote			20,000										
Operator Wages ($/h)	OW	MSC quote ($21.56/hr)			$21.56										
Operator Hours per Shift (h)	OH				0.50										
Shifts per Year	SY	3 shifts/day*365 days/year			1,095										
Maintenance Wages ($/h)	MW	MSC quote			$23.72										
Maintenance Hours per Shift	MH				0.25										
Interest Rate	IR				5.50%										
Equipment Life (y)	EL				30										
NOx Emission Rate (g/bhp-h)	NER	Uncontrolled NOx Emissions >500 bhp			8.0										

APPENDIX 27

Cost Analysis for NSCR for rich-burn engines

Based on E - C/R INC's Cost-Analysis done					
for EPA in June 2010					
HP	100	300	800	1500	3000
Hrs	8760	8760	8760	8760	8760
Total Capital Cost (TCC) in 2010	$15,139.00	$17,240.00	$33,103.00	$44,223.00	$89,644.00
Total Capital Cost (TCC) in 2020 (CPI 1.18)	$17,864.02	$20,343.20	$39,061.54	$52,183.14	$105,779.92
Total Annual Operating Cost (TAOC)	$5,466.00	$8,465.00	$10,723.00	$12,306.00	$18,773.00
Total Annual Operating Cost (TAOC) in 2020 (CPI 1.18)	$6,449.88	$9,988.70	$12,653.14	$14,521.08	$22,152.14
Uncontrolled NOx Gms/bhp-hr	16	16	16	16	16
Uncontrolled NMHC Gms/bhp-hr	1.00	1.00	1.00	1.00	1.00
Uncontrolled NOx tons per year	15.44	46.31	123.49	231.54	463.08
Uncontrolled NMHC tons per year	0.96	2.89	7.72	14.47	28.94
NOx removed TPY (80% Eff.)	12.35	37.05	98.79	185.23	370.47
NMHC removed TPY (50% Eff.)	0.48	1.45	3.86	7.24	14.47
Total NOx, NMHC removed	12.83	38.49	102.65	192.47	384.94
Cost-Effectiveness ($/Ton NOx removed) 2010 Dollars	$522.30	$269.62	$128.08	$78.39	$59.80
Cost-Effectiveness in 2020 Dollars with CPI 1.18	$616.32	$318.16	$151.13	$92.50	$70.56
Uncontrolled NOx Emissions used for this cost analysis - 16 gms/bhp-hr					
Uncontrolled NMHC Emissions used for this cost analysis - 1.0 gms/bhp-hr					
Typical NOx Control Efficiency 80%					
HC Control Efficiency 50%					
TCC = Direct Costs (DC) + Indirect Costs (IC)					
DC = Purchased Equipment Cost (PEC) + Direct Installation Costs (DIC)					
PEC includes Costs for Control Device and Auxiliary Equipment (EC), Instrumenttation (10% of EC), and					
Sales Tax and Fright (6% each of EC)					
DIC includes Foundation and Supports (8% of PEC), Handling and Erection (14% pf PEC), and					
Electric (4% of PEC), Piping (2% of PEC), insulation (1% of PEC), and painting (1% of PEC)					
IC Indirect Installation Costs (ICC) + Contingencies (C)					
ICC includes Engineering (10% of PEC), Construction and Field expenses (5% of PEC), Contractor Fees (10% of PEC),					
Startup (2% of PEC), and Performance test (1% of PEC)					
C is assumed to be 3% of PEC					
TAC = DAC + IAC					
DAC includes Utilities, Operating Labor, maintenance, Annual Compliance test, Catalytic Cleaning					
Catalyst replacement, Catalyst Disposal					
IAC includes Overhead, Fuel Penalty, Property Tax, Insurance, Administrative Charges, and Capital Recovery (10% for 10 years)					

APPENDIX 28

Cost Analysis for oxidation catalyst for IC engines						
	Cost	Costs	Costs	Costs	Costs	Costs
Uncontrolled NMHC gms/hp-hr	1	1	1	1	1	1
HP	2500	2000	1500	1000	750	500
Hrs/Yr	8760	8760	8760	8760	8760	8760
Capital Cost:						
TOTAL CAPITAL COST (TCC) (2009)	$35,069.00	$28,669.00	$22,269.00	$15,869.00	$12,669.00	$9,469.00
Direct Annual Costs						
On-Site Testing	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00
Catalyst replacement (3 yrs Operating life)	$11,689.67	$9,556.33	$7,423.00	$5,289.67	$4,223.00	$3,156.33
Maintenance (5% of TCC)	$1,753.45	$1,433.45	$1,113.45	$793.45	$633.45	$473.45
Indirect Annual Costs						
Capital Recovery (5.5 % @ 20 yrs)	$2,935.28	$2,399.60	$1,863.92	$1,328.24	$1,060.40	$792.56
Overhead (60% of Maintenance - OAQPS)	$1,052.07	$860.07	$668.07	$476.07	$380.07	$284.07
PropertyTax+Ins.+Admn. (4% of TCC - OAQPS)	$1,402.76	$1,146.76	$890.76	$634.76	$506.76	$378.76
TOTAL ANNUALIZED COST	$23,833.22	$20,396.21	$16,959.20	$13,522.18	$11,803.68	$10,085.17
Total Uncontrolled NMHC emissions in Tons per Year	24.12	19.30	14.47	9.65	7.24	4.82
Total NMHC Removed in Tons per Year (60%)	14.47	11.58	8.68	5.79	4.34	2.89
Cost-Effectiveness ($/Ton NMHC removed) in 2009	$1,646.92	$1,761.77	$1,953.19	$2,336.02	$2,718.86	$3,484.53
COST-EFFECTIVENESS ($/Ton NMHC removed) in 2020 with CPI	$1,976.31	$2,114.13	$2,343.83	$2,803.23	$3,262.63	$4,181.43

Reference: June 29, 2010-Control Costs for Existing Stationary SI RICE
From: Bradley Nelson, EC/R, Inc.To: Melanie King, EPA OAQPS/SPPD/ESG
https://19january2017snapshot.epa.gov/sites/production/files/2014-02/documents/5_2011_ctrlcostmemo_exist_si.pdf

APPENDIX 29

Cost Analysis for SCR for container glass and fiber glass furnace				
Cost estimate	OWENS-BROCKWAY GLASS CONTAINER INC/CRENSHAW starting at 4 lbs/ton	OWENS BROCKWAY GLASS/CHERRY ST container starting at 4 lbs/ton	ARDAGH GLASS PORT ALLEGANY PLT container starting at 4 lbs/ton	Factors Used
Boiler Capacity MMBtu/hr	70.2	66.3	51.65	From EPA Alternate Control Glass 1994
Hrs/Yr	8760	8760	8760	
NOx emissions (lb/MMBtu)	0.77	0.78	0.91	container 12 lb/ton: flat 22: pressed 22
TOTAL CAPITAL COST				other 18
DIRECT CAPITAL COST				
Equipment Cost (EC) = (1)	$2,975,852.00	$2,975,852.00	$2,975,852.00	manipulated to agree with line 32 for 250 mmbtu
Auxillaries = (2)				
Instrumentation & Controls = (3)	$297,585	$297,585	$297,585	10% of EC
Sales Tax (6% of EC) = (4)	$178,551	$178,551	$178,551	6% of EC
Freight (6% of EC) = (5)	$178,551	$178,551	$178,551	6% of EC
Total Equipment Cost (TEC) = (6) = (1)+(2)+(3)+(4)+(5)	$3,630,539	$3,630,539	$3,630,539	
INSTALLATION COSTS				
Direct Installation				
Foundation and Support = (7)	$290,443	$290,443	$290,443	8% of TEC
Handling and Erection = (8)	$508,276	$508,276	$508,276	14% of TEC
Electrical = (9)	$145,222	$145,222	$145,222	4% of TEC
Piping (10)	$72,611	$72,611	$72,611	2% of TEC
Insulation for duct work (11)	$36,305	$36,305	$36,305	1% of TEC
Painting (12)	$36,305	$36,305	$36,305	1% of TEC
Total Direct Installation Cost = (13) = (7)+(8)+(9)+(10)+(11)+(12)	$1,089,162	$1,089,162	$1,089,162	
Indirect Installation				
Engineering and Supervision = (14)	$363,054	$363,054	$363,054	10% of TEC
Construction, Field = (15)	$181,527	$181,527	$181,527	5% of TEC
Construction or Contractor Fees = (16)	$363,054	$363,054	$363,054	10% of TEC
Contingencies = (17)	$108,916	$108,916	$108,916	3% of TEC
Startup and performance Tests = (18)	$108,916	$108,916	$108,916	3% of TEC
Total Indirect Cost = (19) = (14)+(15)+(16)+(17)+(18)	$1,125,467	$1,125,467	$1,125,467	
TOTAL CAPITAL COST (TCC) = 20 = (6) + (13) + (19)	$5,845,168	$5,845,168	$5,845,168	EPA cost spreadsheet for 250 MMBtu (Appendix 7)
Direct Annual Costs				
Elecricity = (22)	$76,124	$76,124	$76,124	$0.0676 kw/hr (prorated from 200 MMBtu quote)
Chemical Cost (Urea/Ammonia) = (23)	$103,303	$103,303	$103,303	from EPA cost spreadsheet for 250 MMBtu
Catalyst Replacement (costs/No. of years) = (24)	$23,764	$23,764	$23,764	from EPA cost spreadsheet for 250 MMBtu
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day = (28)	$32,850	$32,850	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material = (29)	$32,850	$32,850	$32,850	100% of maintenance labor
Indirect Annual Costs				
Administration (3% of maintenance+labor) = (25)	$3,154	$3,154	$3,154	3% ofmaintenance +labor
Property Taxes (1% of TCC-OAQPS) = (26)	$58,452	$58,452	$58,452	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS) = (27)	$58,452	$58,452	$58,452	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (30 yrs at 5.5%) = (21)	$402,148	$402,148	$402,148	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost) = (30)	$39,420.00	$39,420.00	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST = (31) = Sum from (21) through (30)	$830,515	$830,515	$830,515	
Uncontrolled NOx TPY = (32)	238.27	227.76	204.98	
NOx removed TPY (80% Eff.) = (33)	190.62	182.21	163.99	
COST EFFECTIVENESS ($/Ton of NOx removed) = (34) = (31)/(33)	$4,356.97	$4,558.06	$5,064.51	
Calculated theoretical emissions after control (lbs NOx/ton glass)	0.80	0.80	0.80	% remainder after control*uncontrolled
RACT II emission limit (lbs NOx/ton glass) and §129.304	4.00	4.00	4.00	

APPENDIX 30

Cost Analysis for SCR for all other glass furnaces		
Cost estimate	PQ CORP/CHESTER other starting at 6 lbs/ton	Factors Used
Boiler Capacity MMBtu/hr	51.65	From EPA Alternate Control Glass 1994
Hrs/Yr	8760	
NOx emissions (lb/MMBtu)	1.35	container 12 lb/ton: flat 22: pressed 22
TOTAL CAPITAL COST		other 18
DIRECT CAPITAL COST		
Equipment Cost (EC) = (1)	$2,975,852.00	manipulated to agree with line 32 for 250 mmbtu
Auxillaries = (2)		
Instrumentation & Controls = (3)	$297,585	10% of EC
Sales Tax (6% of EC) = (4)	$178,551	6% of EC
Freight (6% of EC) = (5)	$178,551	6% of EC
Total Equipment Cost (TEC) = (6) = (1)+(2)+(3)+(4)+(5)	$3,630,539	
INSTALLATION COSTS		
Direct Installation		
Foundation and Support = (7)	$290,443	8% of TEC
Handling and Erection = (8)	$508,276	14% of TEC
Electrical = (9)	$145,222	4% of TEC
Piping (10)	$72,611	2% of TEC
Insulation for duct work (11)	$36,305	1% of TEC
Painting (12)	$36,305	1% of TEC
Total Direct Installation Cost = (13) = (7)+(8)+(9)+(10)+(11)+(12)	$1,089,162	
Indirect Installation		
Engineering and Supervision = (14)	$363,054	10% of TEC
Construction, Field = (15)	$181,527	5% of TEC
Construction or Contractor Fees = (16)	$363,054	10% of TEC
Contingencies = (17)	$108,916	3% of TEC
Startup and performance Tests = (18)	$108,916	3% of TEC
Total Indirect Cost = (19) = (14)+(15)+(16)+(17)+(18)	$1,125,467	
TOTAL CAPITAL COST (TCC) = 20 = (6) + (13) + (19)	$5,845,168	EPA cost spreadsheet for 250 MMBtu (Appendix 7)
Direct Annual Costs		
Elecricity = (22)	$76,124	$0.0676 kw/hr (prorated from 200 MMBtu quote)
Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day = (28)	$32,850	Maintenance Labor - $60/hr, 30 min/shift, 3 shifts/day
Maintenance Material = (29)	$32,850	100% of maintenance labor
Chemical Cost (Urea/Ammonia) = (23)	$103,303	from EPA cost spreadsheet for 250 MMBtu
Catalyst Replacement (costs/No. of years) = (24)	$23,764	from EPA cost spreadsheet for 250 MMBtu
Indirect Annual Costs		
Administration (3% of maintenance+labor) = (25)	$3,154	3% ofmaintenance +labor
Property Taxes (1% of TCC-OAQPS) = (26)	$58,452	1% of TCC (OAQPS)
Insurance (1% of TCC-OAQPS) = (27)	$58,452	1% of TCC (OAQPS)
Annulized Capital Recovery Cost (5.5% @ 30 yrs) = (21)	$402,148	TCC*0.0688
Overhead (44% of Labor cost + 12% Material Cost) = (30)	$39,420.00	60% of Maintenance Cost (OAQPS)
TOTAL ANNUALIZED COST = (31) = Sum from (21) through (30)	$830,515	
Uncontrolled NOx TPY = (32)	304.85	
NOx removed TPY (80% Eff.) = (33)	243.88	
COST-EFFECTIVENESS ($/Ton NOx removed) = (34) = (31)/(33)	$3,405.45	
Calculated theoretical emissions after control (lbs NOx/ton glass)	1.20	% remainder after control*uncontrolled
RACT II emission limit (lbs NOx/ton glass) and §129.304	6.00	