CHESAPEAKE BAY FOUNDATION
Saving a National Treasure

May 9, 2017

George (Tad) Aburn
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Submitted via Electronic Mail

RE: Comments on MDE Process for Setting Reasonably Available Control Technology (RACT) Limits for NOx Emissions from Large Municipal Waste Combustors

Dear Mr. Aburn:

The Chesapeake Bay Foundation (CBF) submits the following comments and recommendations in regards to the public stakeholder process conducted by the Maryland Department of the Environment (MDE) to set Reasonably Available Control Technology (RACT) limits for nitrogen oxides (NOx) emissions from Maryland's two large municipal waste combustors ("MWCs"). The two MWCs are Wheelabrator Baltimore, L.P. ("Wheelabrator") and the Montgomery County Resource Recovery Facility (MCRRF). These comments focus on Wheelabrator Baltimore.

CBF representatives participated in the second public stakeholder meeting held on January 17, 2017. CBF submitted preliminary comments on February 3, 2017. The following comments provide MDE with CBF's recommendations for the RACT analysis and rulemaking process. In an effort to provide MDE with the most useful feedback possible, CBF worked with two expert consultants to inform the following comments and recommendations: Dr. H. Andrew Gray, to conduct air modeling, and Dr. Ranajit Sahu, to conduct an engineering analysis. Their reports are included here as Attachments A and B. The RACT standard for NOx emissions from Wheelabrator is an important piece of MDE's overall strategy to reduce NOx emissions and ozone pollution in the State. CBF encourages MDE to take this opportunity to require significant emission reductions from the facility.

Background

The Wheelabrator Baltimore facility is a municipal waste incinerator that began operations in 1985 and now processes up to 2,250 tons of waste per day.[1] The facility consists of three large mass burn waterwall combustors. As a waste-to-energy facility, Wheelabrator is recognized as a Tier 1 Renewable Energy Facility pursuant to Maryland's Renewable Energy Portfolio Standard ("RPS").[2] Accordingly, it appears that Wheelabrator

[1] Wheelabrator, https://www.wtienergy.com/plant-locations/energy-from-waste/wheelabrator-baltimore.
[2] *See* Md. Code Ann., Pub. Util. § 7-701.

received almost $3.5 million dollars in renewal energy credits (RECs) in 2015. [3] The intent of the RPS is to recognize the benefits of Renewable Energy Facilities, which are presumed to result in "long-term decreased emissions" and "a healthier environment."[4] Notably, and also in 2015, MDE reported that Wheelabrator Baltimore emitted 1,123 tons of NOx—an increase from 2013 and 2014 emissions—and was the sixth largest source of NOx emissions in Maryland.[5]

Water Quality Impacts

In December of 2010, the U.S. Environmental Protection Agency (EPA) issued the Chesapeake Bay Total Maximum Daily Load ("Bay TMDL") for Nitrogen, Phosphorus, and Sediment.[6] Each of the six watershed States and the District of Columbia then developed Watershed Implementation Plans ("WIPs") which detail each jurisdiction's strategy to meet the pollution reduction goals of the Bay TMDL.[7] Collectively, the Bay TMDL and the WIPs constitute the Chesapeake Bay Clean Water Blueprint. CBF is dedicated to the success of the Blueprint, including Maryland's WIPs and local water quality goals.

At the time the Bay TMDL was established, atmospheric deposition of nitrogen was the largest source of nitrogen to the Chesapeake Bay watershed; nitrogen oxides (NOx) are the primary source of this atmospheric nitrogen.[8] Maryland—like all jurisdictions within the Chesapeake Bay watershed—is subject to a specific nitrogen allocation in the Bay TMDL.[9]

CBF commissioned Dr. H. Andrew Gray to conduct air modeling, using the CALPUFF model, to estimate the amount of nitrogen deposited to land and water within the Chesapeake Bay watershed from Wheelabrator's NOx emissions. The full results and methodology of this modeling are detailed in the enclosed report, Attachment A. The air modeling results showed that Wheelabrator's NOx emissions lead to the deposition of an

[3] Pub. Serv. Comm'n of Md., Renewable Energy Portfolio Standard Report, App. A, p. 19 (Jan. 2017), *available at* http://www.psc.state.md.us/wp-content/uploads/RPS-Report-2017.pdf (Page 7 of the Report identifies the average cost of a non-solar Tier 1 REC between 2008 and 2015 as $13.87. Page 19 indicates that Wheelabrator retired 248,377 RECs in 2015; 248,377 RECs at $13.87 equals $3,444,988.).

[4] *See* Md. Code Ann., Pub. Util. § 7-702(b)(1).

[5] MDE PowerPoint Presentation, "NOx RACT for Municipal Waste Combustors (MWCs): Stakeholder Meeting – January 17, 2017," at slide 14-15, *available at* http://www.mde.state.md.us/programs/regulations/air/Documents/SHMeetings/MunicipalWasteCombustors/MWCNOxRACTPresentation.pdf.

[6] U.S. EPA, Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus, and Sediment (Dec. 2010), *available at* https://www.epa.gov/chesapeake-bay-tmdl/chesapeake-bay-tmdl-document.

[7] *See e.g.*, MDE, Md.'s Phase II Watershed Implementation Plan for the Chesapeake Bay TMDL (Oct. 2012), http://www.mde.state.md.us/programs/Water/TMDL/TMDLImplementation/Pages/FINAL_PhaseII_WIPDocument_Main.aspx.

[8] Bay TMDL at Appendix L: Setting the Chesapeake Bay Atmospheric Nitrogen Deposition Allocations, at L-1 (Dec. 2010), https://www.epa.gov/sites/production/files/2015-02/documents/appendix_l_atmos_n_deposition_allocations_final.pdf; *see also*, U.S. EPA, Office of Air Quality Planning & Standards, "Technical Bulletin: Nitrogen Oxides (NOx), Why and How They Are Controlled," at 1 (Nov. 1999), https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf.

[9] Bay TMDL, Section 9. Chesapeake Bay TMDLs, "Table 9-1. Chesapeake Bay TMDL total nitrogen (TN) annual allocations (pounds per year) by Chesapeake Bay segment to attain Chesapeake Bay WQS," at 9-2 (2010), *available at* https://www.epa.gov/sites/production/files/2014-12/documents/cbay_final_tmdl_section_9_final_0.pdf.

estimated 94,179 pounds of nitrogen per year (almost 43 metric tons) to land and water within the Chesapeake Bay watershed; of that total, an estimated 40,973 lbs/year are deposited to land and water within Maryland. *See* Att. A, Table 3.

The 94,179 pounds of nitrogen deposited within the Bay watershed accounts for about 14 percent of Wheelabrator's annual nitrogen emissions (emitted as NOx). *See* Att. A, at 15. A portion of this nitrogen is deposited directly to tidal waters. However, a greater amount of nitrogen (about 95% of the nitrogen deposited via NOx emissions from Wheelabrator) falls upon land surfaces in the Bay watershed. Maryland and its local governments are responsible for managing this land-based nitrogen deposition in the State through the installation of expensive stormwater and agricultural best management practices.[10]

Human Health Impacts

NOx is a primary contributor to ground-level ozone, a pollutant that has numerous, well-documented negative human health impacts.[11] "Baltimore has historically measured some of the highest ozone in the East."[12] Nitrogen dioxide (NO_2), a species of NOx and precursor to ozone, can also have negative impacts to human health.

> Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO_2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO_2.[13]

NO_2 is a criteria pollutant for which the Clean Air Act (CAA) requires EPA to establish National Ambient Air Quality Standards (NAAQS).[14] The NAAQS for NO_2 include two types of standards: primary standards, to protect public health, and secondary standards, to protect the public welfare, including environmental resources. The NAAQS for NO_2 are as

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[10] *See* Bay TMDL, App. L, at L-23 ("The deposition on the land becomes part of the allocated load to the jurisdictions…once the nitrogen is deposited on the land, it would be managed and controlled along with other sources of nitrogen that are present on that parcel of land…In contrast, the nitrogen deposition directly to the Bay's tidal surface waters is a direct loading with no land-based management controls and, therefore, needs to be linked directly back to the air sources and air controls as EPA's allocation of atmospheric nitrogen deposition.").
[11] EPA, Ozone Basics, https://www.epa.gov/ozone-pollution/ozone-basics; *see also*, EPA, Ozone (O_3) Standards – Risk and Exposure Assessments from Current Review, https://www.epa.gov/naaqs/ozone-o3-standards-risk-and-exposure-assessments-current-review.
[12] MDE PowerPoint Presentation, *supra* note 5, at slide 5.
[13] *See* EPA, Nitrogen Dioxide (NO_2) Pollution, https://www.epa.gov/no2-pollution/basic-information-about-no2; *see also*, EPA, Policy Assessment for the Review of the Primary National Ambient Air Quality Standards for Oxides of Nitrogen (Apr. 2017), https://www.epa.gov/sites/production/files/2017-04/documents/policy_assessment_for_the_review_of_the_no2_naaqs_-_final_report.pdf.
[14] EPA, NAAQS Table, https://www.epa.gov/criteria-air-pollutants/naaqs-table.

follows: a primary standard of 100 parts per billion ("ppb") as a one-hour average and 53 ppb averaged over a year; and a secondary standard of 53 ppb averaged over a year.[15]

CBF commissioned Dr. Gray to conduct air modeling, using AERMOD, to estimate the local and regional concentrations of NO_2 resulting from Wheelabrator's emissions. As explained in more detail in the air modeling report enclosed as Attachment A, Wheelabrator's emissions contribute NO_2 to the neighboring communities surrounding the facility. Specifically, "the model indicated that the maximum 1-hour NO_2 concentration due to Wheelabrator exceeded 50 µg/m3 [26.6 ppb] over an area of approximately 11.4 sq. km." *See* Att. A, Table 1/Figure A.6. Although the modeling results do not show a violation of the 1-hour NO_2 NAAQS, the results "indicate that the Wheelabrator facility, on its own, contributes more than one-fourth (28 percent) of the allowable 1-hour NAAQS design value for the cumulative impact from all sources in the community." *See* Att. A, at 7.

In short, Wheelabrator Baltimore contributes a significant amount of NO_2 to the communities surrounding the facility. Both short-term and long-term exposure to NO_2 can lead to negative human health impacts. A stringent NOx RACT standard will reduce the amount of NOx, including NO_2, that is emitted from the Wheelabrator incinerator.

NOx Regulation in Maryland

Acknowledging the significant environmental and human health impacts resulting from NOx emissions, CBF appreciates MDE's previous and ongoing efforts to address NOx pollution and reach ozone attainment levels in Maryland. CBF supports MDE's Clean Air Act Section 126 Petition submitted to the EPA on November 16, 2016.[16] In the Petition, MDE notes that Maryland has worked diligently for years to reduce harmful regional emissions and continues to put forth its best efforts. The current NOx RACT rulemaking is an important moment for MDE to reaffirm this effort to protect human health and the environment.

MDE is conducting the current rulemaking process pursuant to Section 182 of the federal CAA, which requires states to establish RACT standards for major sources of NOx located in areas that are in violation of ozone pollution limits (i.e., "nonattainment areas") and EPA's 2008 ozone implementation rule.[17] The Code of Maryland Regulations defines RACT as "the lowest emissions limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility."[18]

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[15] *Id*.
[16] MDE, Petition to the U.S. EPA Pursuant to Section 126 of the Clean Air Act (Nov. 16, 2016), *available at* http://news.maryland.gov/mde/wp-content/uploads/sites/6/2016/11/MD_126_Petition_Final_111616.pdf.
[17] *See* 42 U.S.C. § 7511a; *see also*, EPA, Current Nonattainment Counties for All Criteria Pollutants, https://www3.epa.gov/airquality/greenbook/ancl.html (listing Baltimore in nonattainment for the 2008 8-hour ozone standard); Implementation of the 2008 National Ambient Air Quality Standards for Ozone: State Implementation Plan Requirements, 80 Fed. Reg. 12264 (Mar. 6, 2015).
[18] COMAR 26.11.01.01(40); *see also*, Memorandum from Roger Strelow, Assistant Admin., Air and Waste Mgmt., U.S. EPA, to Regional Administrators, Regions I-X, Guidance for Determining Acceptability of SIP Regulations in Non-Attainment Areas, at 3 (Dec. 9, 1976), *available at*

Sections 172(c)(1) and 182(b)(2) of the CAA require states to implement RACT for major stationary sources in areas classified as moderate (and higher) non-attainment for ozone. Section 184(b)(1)(B) of the CAA requires RACT for major stationary sources in states located in the Ozone Transport Region (OTR). NOx RACT emission limits vary within the OTR and a variety of technologies are used to control NOx emissions.[19] Wheelabrator contributes to areas designated by EPA as "nonattainment" for ozone and is located within Maryland, an OTR member state.[20]

Comments and Recommendations re: the NOx RACT Standard

In recognition of the impacts to water quality and human health from Wheelabrator's NOx emissions, MDE should use its authority to require significant NOx reductions at Wheelabrator Baltimore. MDE has indicated that it is considering a 24-hour daily RACT standard between 165 and 180 ppmvd @7% 0_2.[21] However, prior to establishing the NOx RACT standard, MDE should conduct a thorough evaluation of whether Wheelabrator Baltimore can implement a hybrid SNCR/SCR control system. Such a hybrid system would allow for NOx reductions of up to 75% and would warrant a NOx RACT limit closer to 50 ppmvd. If, *and only if*, hybrid SNCR/SCR is determined to be unavailable for Wheelabrator—after thorough review by MDE, including analysis of all information discussed in Attachments B and C, and public input—MDE should set a daily RACT standard of no higher than 150 ppmvd, as demonstrated in other OTR states for MWCs similar to Wheelabrator Baltimore.

I. MDE Should Thoroughly Investigate Hybrid SNCR/SCR as a NOx Control Option for Wheelabrator Baltimore.

Hybrid SNCR/SCR involves a hybrid combination of a Selective Non-Catalytic Reduction (SNCR) NOx control system (the existing technology at Wheelabrator) and one or more layers of Selective Catalytic Reduction (SCR) catalyst placed at the appropriate locations in the gas path. *See* Sahu Report, Att. B, at 4. Hybrid SNCR/SCR control systems allow for significant NOx reductions between 50 and 75%. *See id*. MDE should thoroughly evaluate whether a hybrid SNCR/SCR system is a feasible control option for Wheelabrator Baltimore. In order to conduct this thorough evaluation, MDE must request additional information from Wheelabrator.[22]

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https://www3.epa.gov/ttn/naaqs/aqmguide/collection/cp2/19761209_strelow_ract.pdf ("RACT should represent the toughest controls considering technological and economic feasibility that can be applied to a specific situation.").

[19] Ozone Transport Comm'n, Stationary Area Sources Committee, White Paper on Control Technologies and OTC State Regulations for Nitrogen Oxides (NOx) Emissions from Eight Source Categories, at 28–30 (Feb. 10, 2017), *available at* http://www.otcair.org/upload/Documents/Reports/OTC_White_Paper_NOx_Controls_Regs_Eight_Sources_Final_Draft_02152017.pdf.

[20] EPA, 8-Hour Ozone (2008) Designated Area/State Information, https://www3.epa.gov/airquality/greenbook/hbtc.html.

[21] *See* MDE PowerPoint Presentation, *supra* note 5, at slide 23.

[22] COMAR 26.11.01.05(A) ("The Department may require a person who owns or operates an installation or source to establish and maintain records sufficient to provide the information necessary to…[a]ssist the Department in the development of an…air emissions standard…").

As MDE acknowledged at a 2016 Air Quality Control Advisory Council Meeting, "Maryland MWCs have demonstrated the potential to reduce NOx emissions through analysis and optimization of existing controls."[23] However, based on the publicly available information, CBF is concerned with the adequacy of Wheelabrator's optimization study, as detailed by Dr. Sahu in Attachment B. At the January 17, 2017 Stakeholder Meeting, Wheelabrator claimed technical limitations at the facility that, in Wheelabrator's opinion, narrow the scope of feasible optimization and control technologies. MDE should request the additional information, described herein and attached, from Wheelabrator so that it can adequately analyze these claims and consider the possibility of a hybrid SNCR/SCR system. *See* Att. B. Any claim of technical infeasibility must be thoroughly supported with evidence provided by Wheelabrator and reviewed by MDE and public stakeholders.

MDE should request clarifying and additional information pertaining to Wheelabrator as detailed by Dr. Sahu in Attachment B including, but not limited to, the following:

i. Computational fluid dynamics (CFD) modeling for the boilers;
ii. Details related to the Quinapoxet Optimization Study, including responses to the list of questions submitted to MDE on April 4, 2017 and enclosed here as Attachment C;
iii. Information regarding NOx generation and fuel composition (i.e., nitrogen,[24] moisture, and oxygen content of the waste stream);
iv. A detailed description of the combustion process.

II. <u>If Hybrid SNCR/SCR is Proven to be Infeasible, MDE Should Set a RACT Standard for MWCs of No Higher Than 150 ppmvd.</u>

A NOx RACT standard for MWCs of 150 ppmvd is technologically and economically feasible, as demonstrated by the RACT standards set for MWCs in neighboring states in the Ozone Transport Region, including MWCs similar to Wheelabrator Baltimore. All MWCs in Connecticut, including two owned and operated by Wheelabrator, L.P., are required to meet a RACT standard of 150 ppmvd.[25] Similarly, all MWCs in New Jersey are required to meet a RACT standard of 150 ppmvd.[26] Three Wheelabrator plants that appear similar to the Wheelabrator Baltimore facility are now, or will soon be, subject to a NOx RACT limit of 150 ppmvd. See section II.A.ii. in the Environmental Integrity Project's comment letter, submitted May 9, 2017, for a more detailed analysis of these three similar incinerator facilities.

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[23] MDE, PowerPoint Presentation, "NOx RACT for Municipal Waste Combustors", at slide 15 (June 6, 2016), http://mde.maryland.gov/programs/workwithmde/Documents/MWC-AQCAC-Briefing-06-06-2016.pdf.

[24] "Because of the relatively low temperatures at which MWC furnaces operate, 70 to 80 percent of NOx formed in MWCs is associated with nitrogen in the waste." EPA, AP 42, Fifth Ed. Compilation of Air Pollutant Emission Factors, Vol. I, Chapter 2: Solid Waste Disposal, at 2.1.3.5 (Oct. 1996), *available at* https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf.

[25] Conn. Agencies Regs. § 22a-174-38(c)(8); *see also*, Ozone Transport Comm'n, White Paper, *supra* note 19, at App. D: Municipal Waste Combustors in Ozone Transport Region (Feb. 10, 2017).

[26] N.J. Admin. Code § 7:27-19.12 (setting standard at 150 ppmvd and providing an option to obtain an alternative standard).

However, in light of the considerable impacts on local and regional water quality and human health due to the significant NOx emissions from Wheelabrator, MDE should *first* pursue a hybrid SNCR/SCR control option for Wheelabrator and the much higher reductions achievable with such a control system.

Conclusion

CBF appreciates MDE's stakeholder process thus far and the opportunity to participate and submit comments. Please do not hesitate to contact us with questions.

Sincerely,

Alison Prost, Esq.
Maryland Executive Director
Chesapeake Bay Foundation

cc:
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ATTACHMENT A

MODELING OF THE WHEELABRATOR BALTIMORE MUNICIPAL WASTE INCINERATOR

Dr. H. Andrew Gray
Gray Sky Solutions
May 9, 2017

The Wheelabrator Baltimore municipal waste incinerator ("Wheelabrator" or "the facility"), located in Baltimore, Maryland, is a large source of nitrogen oxides (NO_X), which contribute to smog and Chesapeake Bay pollution.[1] A computer modeling study was conducted to estimate local NO_2 air quality impacts in addition to the regional deposition rates of nitrogen associated with the NO_X emissions from the Wheelabrator facility.

Two separate modeling exercises were conducted: (1) Short-term and long-term nitrogen dioxide (NO_2) concentration impacts were estimated in the area immediately surrounding the Wheelabrator facility, and (2) Long-term nitrogen deposition impacts were estimated to the Chesapeake Bay Watershed. The methodology and results for these two modeling assessments are presented below.

Local-scale NO_2 Concentration Impacts

The AERMOD model (v16216r) was used to compute hourly NO_2 concentrations in the area surrounding the Wheelabrator facility. Previous modeling of the Wheelabrator facility performed by MDE[2] and Energy Answers[3] were used to satisfy many of the source and meteorological data requirements. The AERMOD inputs, options, and model results are described below:

Source Data

Emission data for the Wheelabrator facility were obtained from EPA's National Emissions Inventory (NEI) for the year 2011.[4] According to EPA's NEI, the

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[1] *See* Order Responding to Petitioners' Request that the Administrator Object to the Issuance of a Title V Operating Permit, In the Matter of Wheelabrator Baltimore, L.P., Permit No. 24-510-01886, at 3 (Apr. 14, 2010) ("The Wheelabrator incinerator is a major stationary source of numerous air pollutants, including sulfur oxides (SOx), nitrogen oxides (NOx), and hazardous air pollutants (HAPs).").
[2] SO_2 Characterization Modeling Analysis for the H.A. Wagner and Brandon Shores Power Plants, Maryland Department of the Environment, April 19, 2016.
[3] Energy Answers, Modeling of Proposed Facility (modeling files, dated Sep. 2012). Energy Answers modeled the Wheelabrator facility as part of a multi-source analysis using AERMOD, which consisted of modeling emissions from a proposed Energy Answers source located near the Baltimore Harbor and other existing sources near the proposed facility.
[4] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

Wheelabrator facility emitted 1,133.54 tons of NO_X in 2011.[5] The NEI 2011 NO_X emission rate for the Wheelabrator facility (1,133.54 tpy = 32.61 g/s) was used for the current AERMOD modeling. Although there are three boilers at the Wheelabrator facility, they are all emitted from the same stack (with identical stack properties), so the entire facility was modeled as a single emission unit.

MDE's recent AERMOD modeling included stack parameter data for the Wheelabrator facility, which were used in the current modeling.[6] The Wheelabrator emissions from the three boilers are exhausted from a stack that is 96.01 m (315 ft) high (with a base elevation of 5.6 m), from three identical ports, each with a diameter of 2.13 m (7 ft). The exhaust temperature was assumed to be 415F (485.93K), and the exhaust velocity was assumed to be 74 fps (22.55 m/s).

<u>Receptor Data</u>

Receptors were placed within a 4 km x 4 km fine grid surrounding the source using 50m grid spacing (there were 81 x 81 = 6,561 fine grid receptors), which was nested inside a 20 km by 20 km coarse grid with 400m grid spacing (there were 2,480 additional coarse grid receptors). The modeling domain is shown in Figure 1, below. Elevations for each fine and coarse grid receptor were determined using the AERMAP program (v11103), for which the 1/3 arc-second National Elevation Dataset (NED) data[7] were input.

<u>Meteorological Data</u>

Two different meteorological data sets were used for the AERMOD modeling of the Wheelabrator facility: (1) the Energy Answers 2005-2009 AERMET data, and (2) a meteorological data set for 2006-2010 developed with AERMET for a previous modeling assessment of two nearby power plants.[8] Both data sets make use of surface meteorological data (hourly data and one-minute wind data) from Baltimore Airport and upper air radiosonde data from Sterling, Virginia.

The model results (see Tables 1 and 2, below) using the two independently developed meteorological data sets were quite similar (especially the modeled NAAQS design values), which may be expected given that (1) the sources of airport meteorological data used to develop both data sets were the same, (2) the same version of AERMET

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[5] Energy Answers modeled the Wheelabrator facility as part of their AERMOD modeling exercise (performed in late 2012). Their modeled NO_X emission rate for Wheelabrator was 37.55 g/s, which is about 15 percent higher than the 2011 NEI total (1133.54 tpy = 32.61 g/s).
[6] Energy Answers used identical stack parameters for Wheelabrator as in MDE's recent modeling. The stack height and diameter were confirmed with GoogleEarth. The source location UTM coordinates were determined using GoogleEarth. The stack is located in UTM zone 18S, at (359352m, 4348001m).
[7] Multi-Resolution Land Characteristics Consortium (MRLC). https://www.mrlc.gov/.
[8] Modeling the Short-term SO_2 Impacts Due to Wagner and Crane Power Plant Emissions, report prepared for Sierra Club by H. Andrew Gray, Gray Sky Solutions. September 2011.

(v11059) was used during the development of both data sets, and (3) four of the five modeled years were the same.[9]

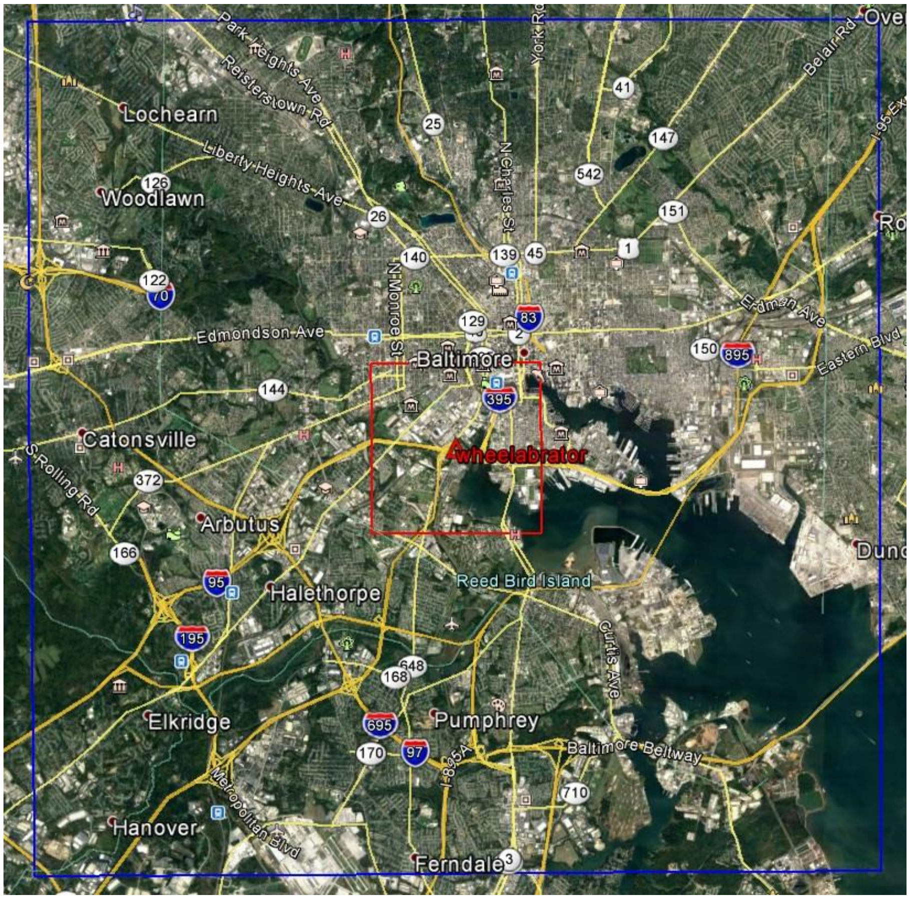

Figure 1. AERMOD Receptor Grids (red: fine 4x4 km 50m grid; blue: coarse 20x20 km 400m grid)

Model Options

The Wheelabrator facility is located in Baltimore, an urban area (est. population: 635,815[10]), and therefore the "URBAN" modeling option was selected within AERMOD. Testing of the model with and without the effects of building downwash confirmed that the plume exiting Wheelabrator's tall stack would be unaffected by any of the nearby buildings (and therefore inclusion of the building downwash parameterization within

[9] Comparison of the two independently developed AERMET meteorological data sets confirmed that the wind speeds and directions were completely identical for the four overlapping years (2006-2009).
[10] Baltimore population (635,815) that was input to AERMOD was identical to the Energy Answers modeled population.

AERMOD was not necessary). The NO_2 conversion rate was assumed to be 100% (i.e., assuming complete conversion of NO_X to NO_2).[11]

Model Results

The AERMOD model was used to estimate the average NO_2 concentration due to Wheelabrator's NO_X emissions for every hour of the five-year modeling period at every fine and coarse grid receptor location. The maximum hourly average NO_2 concentrations were determined at each receptor, as well as the 8th highest hourly average during the five-year modeling period. In addition, concentrations corresponding to the design values for both the 1-hour and annual average NO_2 NAAQS were computed. The design value for the 1-hour NO_2 NAAQS is equal to the 98th percentile (8th highest) daily maximum 1-hour average concentration, averaged over all five model years. The annual average NO_2 design value is equal to the modeled five-year average concentration.

The maximum value for each of the modeled concentration impact metrics discussed above was determined across all modeled receptor locations, as shown in Table 1, below. The AERMOD model results (NO_2 concentrations) in Table 1 can be scaled in proportion to the NO_X emission rate to estimate the NO_2 concentration impacts for a different assumed emission rate.

Table 1 shows the modeled peak NO_2 concentrations (maximum 1-hour average, 8th highest 1-hour average, 1-hour NAAQS design value concentration, and annual average NAAQS design value concentration) that were predicted to occur due to Wheelabrator's NO_X emissions. All modeled peak NO_2 concentrations were located within the fine 4 km x 4 km modeling grid. The table indicates the UTM coordinates of each predicted peak concentration, and the location relative to the Wheelabrator facility.

The AERMOD model predicted that elevated peak concentrations occur over a large area surrounding the Wheelabrator facility. For example, using the 2005-2009 meteorological data, the model indicated that the maximum 1-hour NO_2 concentration due to Wheelabrator exceeded 50 $\mu g/m^3$ (26.6 ppb) over an area of approximately 11.4 sq. km.[12] The peak modeled 1-hour NO_2 concentration exceeded 40 $\mu g/m^3$ (21.3 ppb) across a 26 sq. km area.[13]

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[11] The AERMOD model was tested using various options for the NO_2 conversion, including PVRM, in which the equilibrium NO_2/NO_X ratio (a function of ambient ozone concentrations) is 0.9 (with fairly slow conversion), and the ARM method, which effectively results in an 80% conversion at the locations of the peak concentrations. Using the default 100% conversion may result in a slight overestimation of NO_2 concentrations.

[12] The 11.4 sq. km area in which the maximum modeled 1-hour NO_2 exceeded 50 $\mu g/m^3$ includes 9.8 sq. km (out of the total 16 sq. km) within the fine grid and 1.6 sq. km within the coarse receptor grid.

[13] The 26 sq. km area in which the maximum modeled 1-hour NO_2 exceeded 40 $\mu g/m^3$ includes 14.2 sq. km (out of the total 16 sq. km) within the fine grid and 11.7 sq. km within the coarse receptor grid.

Table 1. AERMOD Model Results: NO_2 Concentration Impacts due to the Wheelabrator Facility

Metric	Concentration µg/m³	Concentration ppb	Location (UTMx, UTMy, m)
Using 2005-2009 Meteorological Data:			
Maximum 1-hour average NO_2 Concentration	68.9	36.6	(360602, 4347851) 1.26 km E
Maximum 8th-high 1-hour average NO_2 Concentration	63.9	34.0	(360602, 4347951) 1.25 km E
1-hour NAAQS Design Value Concentration	52.7	28.0	(360702, 4347851) 1.36 km E
Annual Average Design Value Concentration	2.26	1.20	(360652, 4347901) 1.30 km E
Using 2006-2010 Meteorological Data:			
Maximum 1-hour average NO_2 Concentration	60.3	32.1	(359252, 4349151) 1.15 km N
Maximum 8th-high 1-hour average NO_2 Concentration	56.8	30.2	(358852, 4349151) 1.25 km NNW
1-hour NAAQS Design Value Concentration	53.1	28.2	(360502, 4348301) 1.19 km ENE
Annual Average Design Value Concentration	2.56	1.36	(360652, 4348001) 1.30 km E

Appendix A includes a number of maps and contour plots, showing the spatial extent of the modeled maximum 1-hour average NO_2 concentrations (during the 2005-2009 period; corresponding to the first row of data in Table 1). The area in which the modeled maximum 1-hour average NO_2 concentration exceeded 40 $\mu g/m^3$ is shown in Figures A.3 and A.4, and 50 $\mu g/m^3$ in Figures A.6 and A.7. Figures A.5 and A.8 show 3-D and 2-D contours of the same maximum hourly average NO_2 concentration model results (using different concentration cutoffs).

The AERMOD model was also run using a regional background concentration which varied by the season and hour of the day, as shown in Figure 2.[14] Hourly background NO_2 concentrations, ranging from 21 to 88 $\mu g/m^3$ (11 to 47 ppb) were added to each of the modeled 1-hour average concentrations (due to Wheelabrator) at every receptor. The modeled peak NO_2 concentrations including background are shown in Table 2 (using the same metrics as in Table 1).

[14] The variable background concentration data were identical to the background data used in the Energy Answers AERMOD modeling, and represent an upwind regional background concentration level. The modeled background NO_2 concentration does not include the impacts of other nearby NO_X sources, including transportation sources (automobiles, trucks, buses, and trains), industrial equipment, and other large point sources of NO_X in the area.

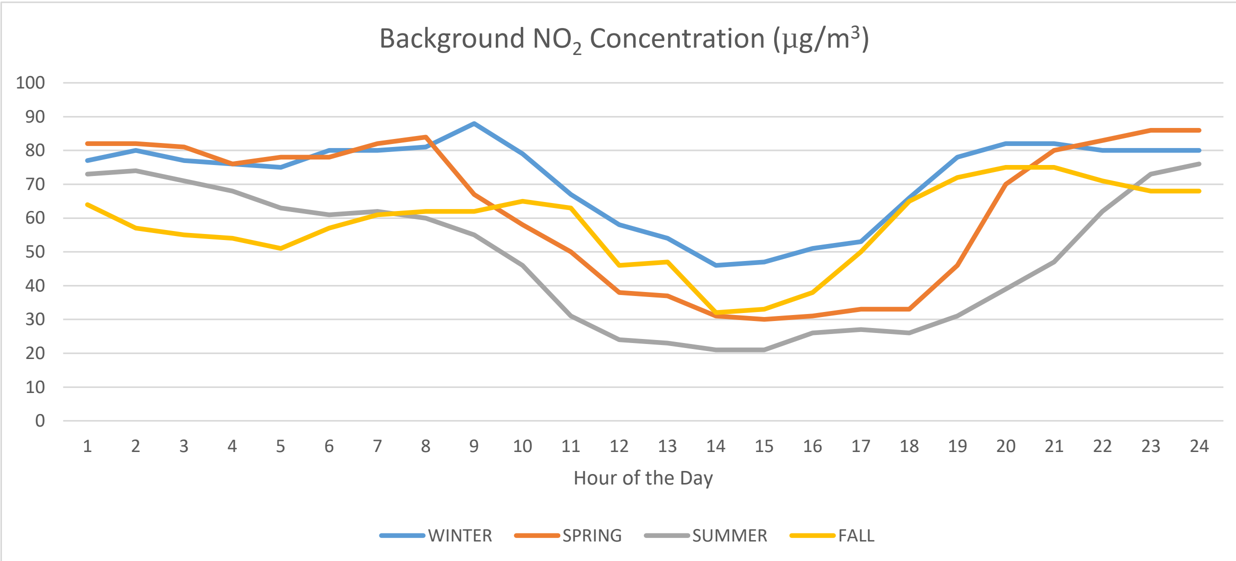

Figure 2. Modeled Background NO_2 Concentration

Table 2. AERMOD Model Results: NO_2 Concentration Impacts due to the Wheelabrator Facility, including Background Concentration

Metric	Concentration µg/m³	Concentration ppb	Location (UTMx, UTMy, m)
Using 2005-2009 Meteorological Data:			
Maximum 1-hour average NO_2 Concentration	152.5	81.1	(360702, 4347851) 1.36 km E
Maximum 8th-high 1-hour average NO_2 Concentration	143.8	76.5	(360602, 4347851) 1.26 km E
1-hour NAAQS Design Value Concentration	129.8	69.0	(360752, 4347901) 1.40 km E
Annual Average Design Value Concentration	62.3	33.1	(360652, 4347901) 1.30 km E
Using 2006-2010 Meteorological Data:			
Maximum 1-hour average NO_2 Concentration	143.5	76.3	(360602, 4347851) 1.26 km E
Maximum 8th-high 1-hour average NO_2 Concentration	136.3	72.5	(360502, 4348151) 1.16 km E
1-hour NAAQS Design Value Concentration	130.5	69.4	(360602, 4348201) 1.27 km E
Annual Average Design Value Concentration	62.6	33.3	(360652, 4348001) 1.30 km E

According to the model results, the emissions from the Wheelabrator facility, together with the regional background NO_2 concentration, would not cause a violation of either the 1-hour or annual NO_2 NAAQS.[15] However all local sources of NO_X were not included in the modeling, including transportation sources and other large point sources.[16] Although the modeled design value does not violate the 1-hour NO_2 NAAQS, the model results (Table 1) indicate that the Wheelabrator facility, on its own, contributes more than one-fourth (28 percent) of the allowable 1-hour NAAQS design value for the cumulative impact from all sources in the community (which includes regional background).

[15] For the 1-hour NO_2 NAAQS, the design value must be below 100 ppb = 188 $\mu g/m^3$. The annual NO_2 NAAQS is violated when the design value exceeds 53 pbb = 100 $\mu g/m^3$.
[16] To properly assess whether there would likely be a violation of the 1-hour NO_2 NAAQS, a modeling study would need to include all local sources of NO_X, including transportation sources (automobiles, trucks, buses, and trains), industrial equipment, and other large point sources of NO_X in the area. In addition, the Wheelabrator facility would need to be modeled using maximum daily emission rates to determine potential peak impacts, rather than the average emission rates used in this modeling study.

Regional-scale Nitrogen Deposition Impacts

The CALPUFF air quality dispersion model (v5.8.5) was used to estimate the deposition of nitrogen to a number of sensitive receptor areas, including the Chesapeake Bay Watershed and other regions within the Chesapeake Bay Watershed. The CALPUFF model was used to simulate the emissions of NO_X and SO_2, and the subsequent transport and atmospheric chemical transformation (into nitric acid and particulate nitrate) for an entire year. Meteorological data from previous CALPUFF modeling[17] of regional sources were used in the current modeling of the Wheelabrator facility. The CALPUFF inputs, options, and model results are described below.

Source Data

Emission data for the Wheelabrator facility were obtained from EPA's National Emissions Inventory (NEI) for the year 2011.[18] According to EPA's NEI, the Wheelabrator facility emitted 1,133.54 tons (32.6 g/s) of NO_X and 261.30 tons of SO_2 (7.5 g/s) in 2011.[19] The NEI 2011 NO_X and SO_2 emission rates for the Wheelabrator facility were used for the current CALPUFF modeling.[20] Although there are three boilers at the Wheelabrator facility, they are all emitted from the same stack (with identical stack properties), so the entire facility was modeled as a single emission unit.

MDE's recent AERMOD modeling included stack parameter data for the Wheelabrator facility, which were also used in the current CALPUFF modeling. The Wheelabrator emissions from the three boilers are exhausted from a stack that is 96.01 m (315 ft) high, from three identical ports, each with a diameter of 2.13 m (7 ft). The exhaust temperature was assumed to be 415F (485.93K), and the exhaust velocity was assumed to be 74 fps (22.55 m/s).

Modeling Domain and Receptor Data

The CALPUFF simulation was conducted within the 792 km x 828 km rectangular modeling domain shown in Figure 3, below. The CALPUFF computational grid consisted of 8,096 (88 x 92) modeled receptor locations, spaced every 9 km within the

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[17] See (1) Gray, H.A., The Deposition of Airborne Mercury within the Chesapeake Bay Region from Coal-fired Power Plant Emissions in Pennsylvania (March 2007), (2) Gray, H.A., Deposition in the Chesapeake Bay Region (February 2009), and (3) Gray, H.A., Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia, report prepared for the Chesapeake Bay Foundation (August 2009).

[18] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

[19] MDE's recent (2016) modeling used an "allowable" SO_2 emission rate for Wheelabrator of 12.6 g/s = 438 tpy. Energy Answers also modeled the Wheelabrator facility as part of their AERMOD modeling exercise (performed in late 2012). Their modeled NO_x emission rate for Wheelabrator was 37.55 g/s, which is about 15 percent higher than the 2011 NEI total (1133.54 tpy = 32.61 g/s).

[20] The NO_x emission rate (1,133.54 tpy) used for the CALPUFF modeling was the same as the NO_X emission rate used in the AERMOD modeling described earlier in this report.

modeling domain. Terrain (elevation) data and surface characteristics data (land-use data, necessary for meteorological data development) were prepared for the gridded modeling domain using the recommended CALPUFF preprocessors.[21]

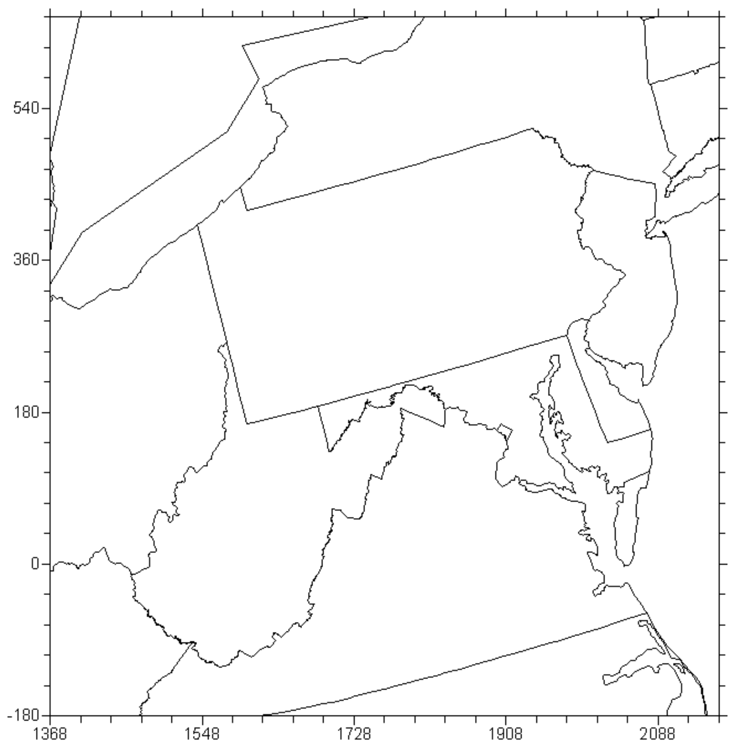

Figure 3. CALPUFF Modeling Domain

There were a number of "sensitive receptor areas" within the modeling domain in which the gridded modeled nitrogen deposition was summed to determine Wheelabrator's overall impact to each area. These receptor areas are described below:

Chesapeake Bay Watershed. The Chesapeake Bay Watershed includes all the land surrounding the streams and tributaries that ultimately flow into the bay, and all the waters of the Chesapeake Bay.[22] The watershed extends through six states and the District of Columbia, from Virginia northward into New York, encompassing an area of approximately 170,000 km^2, as shown in Figure 4. A number of major and secondary rivers empty into the Chesapeake Bay, including the James, York, Rappahannock,

[21] The preparation of the required geophysical data for use in the CALPUFF modeling is described in Appendix A of Gray, H.A., Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia, report prepared for the Chesapeake Bay Foundation (August 2009).
[22] A watershed, or drainage basin, is defined as the bounded area of land (including both land and water) that drains all the streams and rainfall to a common outlet.

Potomac, Patuxent, and Patapsco to the west, the Gunpowder, Bush, Susquehanna, Northeast, Elk, and Sassafras to the north, and the Chester, Choptank, Nanticoke, Wicomico, and Pocomoke to the east.

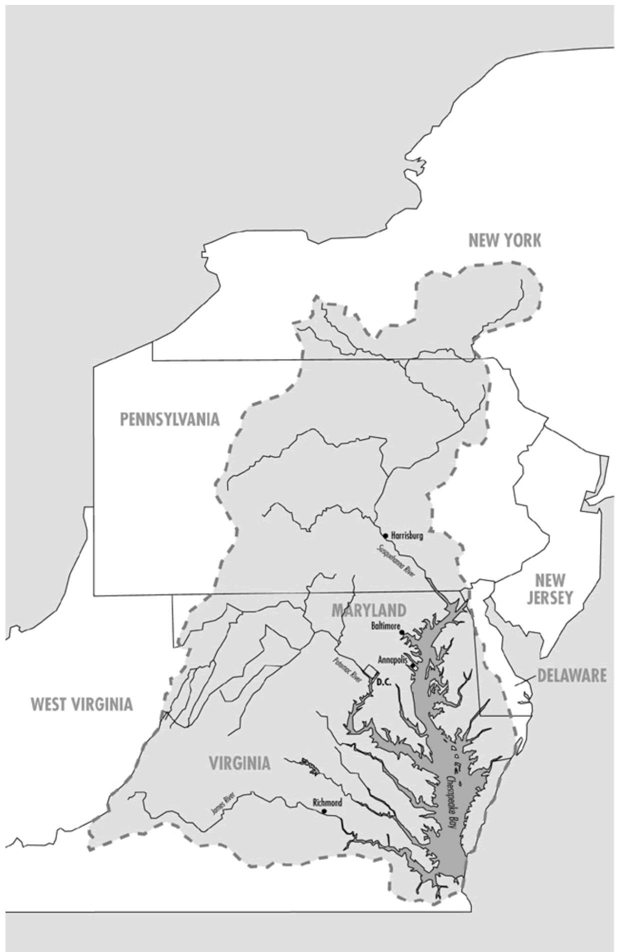

Figure 4. Chesapeake Bay Watershed

Chesapeake Bay. The Chesapeake Bay is the largest estuary in the United States, with an approximate area of 11,600 km^2, as shown in Figure 5. The bay and its shoreline (total shoreline: 18,800 km) are home to a diverse ecosystem of vegetation, fish, and other wildlife. The bay is quite shallow in many places; about one quarter of the area of the bay is less than 2m in depth. The CALPUFF model was used to estimate the deposition of nitrogen directly to the water surface of the Chesapeake Bay, that originated from the Wheelabrator facility.[23]

[23] The modeled deposition to the entire Chesapeake Bay Watershed includes the deposition to the waters of the Chesapeake Bay itself.

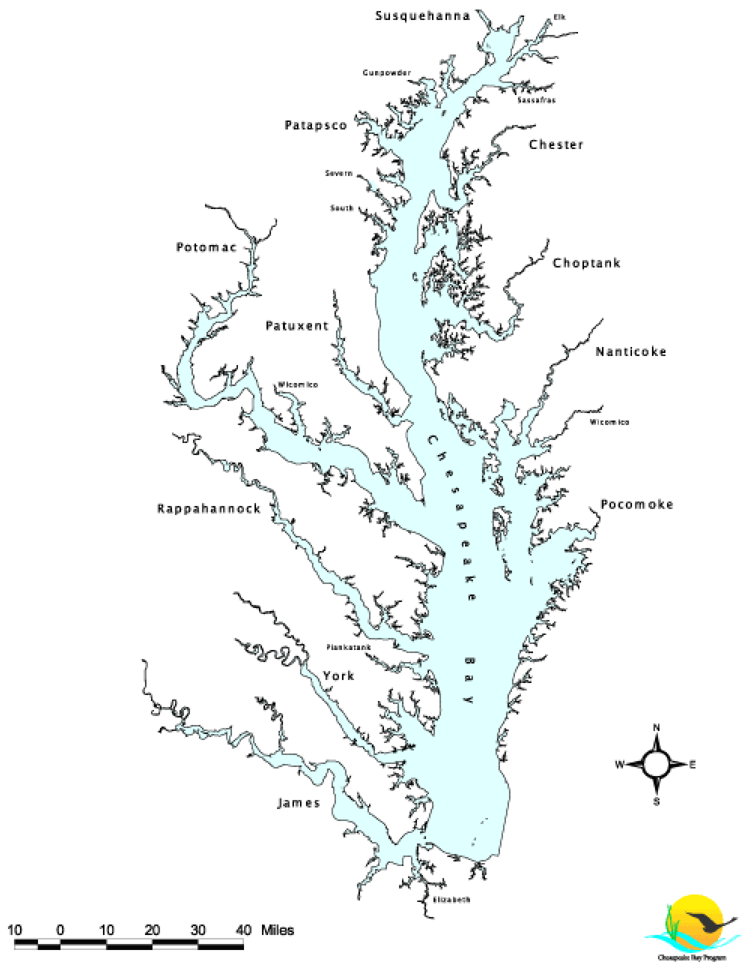

Figure 5. Chesapeake Bay

James River Basin Watershed. The James River Basin Watershed (Figure 6) consists of the region in which precipitation will ultimately drain into the Chesapeake Bay via the James River. The James River Basin Watershed is Virginia's largest river basin; it accounts for almost one-fourth the area of the Commonwealth of Virginia. The watershed includes about 4 percent open water and includes a population of about 2.5 million people. Over 65 percent of the watershed is forested, with 19 percent in cropland and pasture. The remaining 12 percent is considered urban. The James River Basin (USGS accounting unit 020802; area = 26,418 km^2) is made up of eight smaller watersheds: Upper James (USGS cataloging unit 02080201), Maury

(02080202), Middle James-Buffalo (02080203), Rivanna (02080204), Middle James-Willis (02080205), Lower James (02080206), Appomattox (02080207), and Hampton Roads (02080208), as shown in Figure 7.

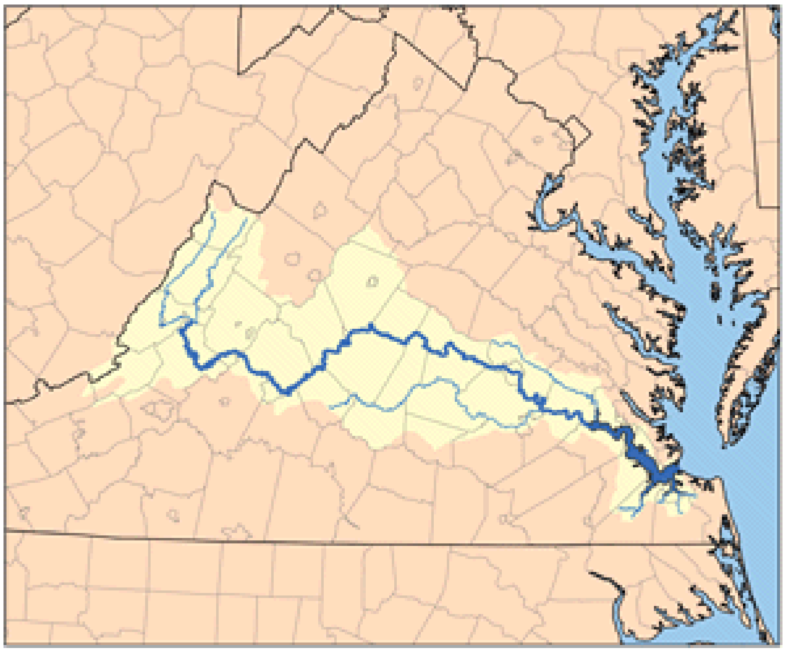

Figure 6. James River Basin Watershed

Including its Jackson River source, the James River is over 400 miles long. It is the twelfth longest river in the United States that remains entirely within one state. The James River forms in the Allegheny Mountains, near Iron Gate on the border between Alleghany and Botetourt counties from the confluence of the Cowpasture and Jackson Rivers, and flows into the Chesapeake Bay at Hampton Roads. Tidal waters extend west to Richmond at its fall line (the head of navigation). Larger tributaries draining to the tidal portion include the Appomattox River, Chickahominy River, Warwick River, Pagan River, and the Nansemond River. The James contributes about 12 percent of the streamflow from the non-tidal part of Chesapeake Bay Basin, making it the third largest streamflow source after the Susquehanna and the Potomac Rivers.

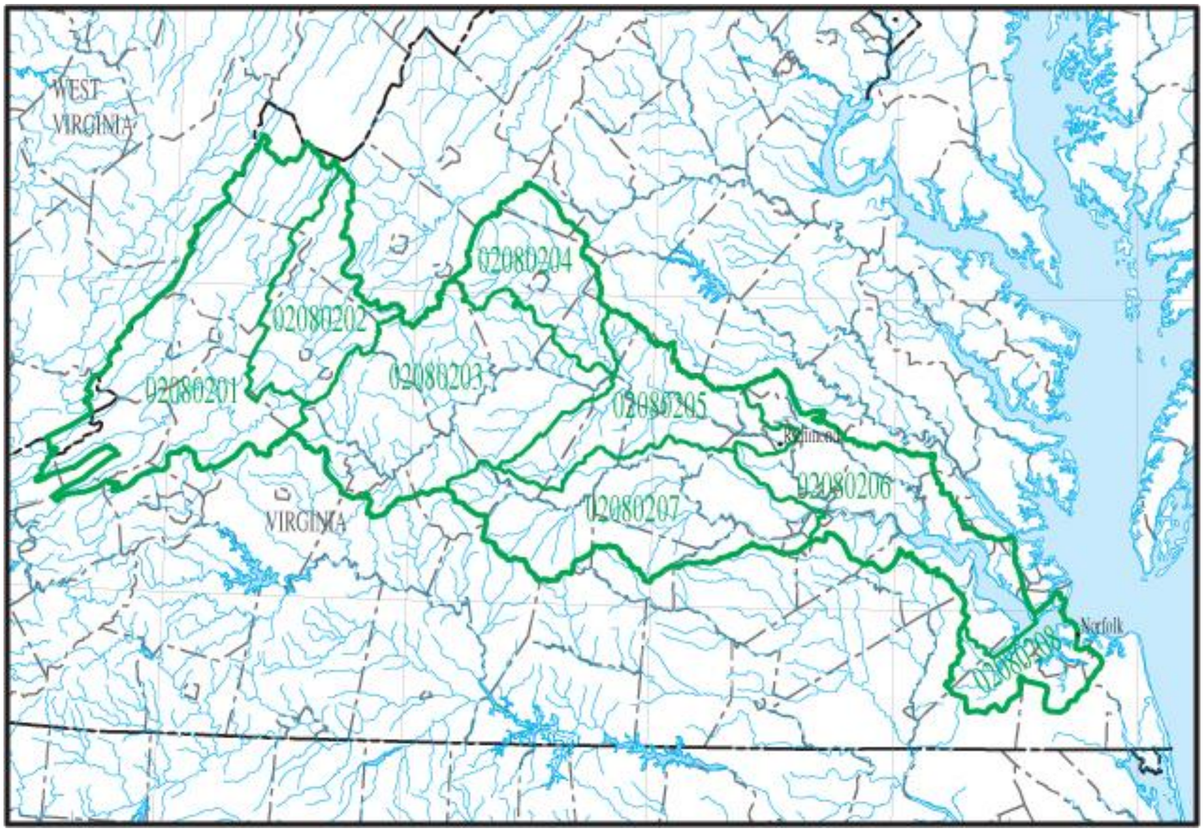

Figure 7. James River Drainage Basin (with USGS Cataloguing Units)

Meteorological Data

The meteorological data that were input to the CALPUFF dispersion model for modeling of the Wheelabrator facility were identical to the meteorological data that were developed for use in previous CALPUFF modeling assessments of numerous sources in the Chesapeake Bay area.[24] Detailed meteorological data for 1996 were obtained from the Penn State/NCAR Mesoscale Modeling System, Version 5 (MM5), a prognostic model with four-dimensional data assimilation. The 36 km MM5 data were augmented by ambient surface meteorological measurements, including wind speed and direction, temperature, and precipitation data. The resulting CALMET-derived data set for 1996 represents a typical annual cycle of meteorology and was used to estimate the long-term deposition impacts due to emissions from the Wheelabrator facility.[25]

[24] Gray, H.A., Deposition in the Chesapeake Bay Region (Feb. 2009)
[25] A detailed description of the meteorological modeling can be found in Appendix A of Gray, H.A., Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia, report prepared for the Chesapeake Bay Foundation (August 2009).

Model Options

The CALPUFF model was used to account for the hourly emissions of NO_X and SO_2, and the subsequent transport, chemical transformation (into nitric acid, nitrate, and sulfate), and deposition of all modeled species.[26] The dry deposition rates for gases and particles are computed within CALPUFF as a function of geophysical parameters and meteorological conditions using a multi-layer resistance model. The rate of deposition to the surface depends on properties of the depositing material (particle size and density for particles; molecular diffusivity, solubility and reactivity for gases), the characteristics of the surface (surface roughness, and vegetation), and atmospheric variables (stability, turbulence intensity). An empirical scavenging coefficient approach is used to compute wet deposition fluxes for gases and particles during precipitation. Pollutant depletion is a function of the hourly precipitation rate and an empirically-derived pollutant-specific scavenging coefficient, which is based on characteristics of the pollutant species (reactivity and solubility) and precipitation type (liquid or frozen).[27]

Model Results

The CALPUFF model was used to estimate the nitrogen deposition at every gridded receptor location within the modeling domain for every hour of the annual simulation. The gridded data were then used to determine annual average rates of nitrogen deposition within each of the sensitive receptor areas described above (Chesapeake Bay Watershed, Chesapeake Bay, and James River Watershed), as shown in Table 3. The annual average modeled nitrogen deposition rates within the entire states of Maryland, Virginia, and Pennsylvania were also computed (see Table 3).

The Wheelabrator facility was modeled assuming the 2011 NO_X and SO_2 NEI emission rates.[28] The CALPUFF model results (annual nitrogen deposition) shown in Table 3 can be (approximately) scaled in proportion to the NO_X emission rate in order to estimate nitrogen deposition impacts for a different assumed emission rate.

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[26] The CALPUFF modeling for the Wheelabrator facility employed the same modeling procedures, CALPUFF modeling options, ozone input data, and POSTUTIL and CALPOST postprocessing procedures as was followed in previous CALPUFF modeling assessments. For details of the modeling protocol, see Appendix A of Gray, H.A. Cypress Creek Power Plant Modeling: Pollutant Deposition to the Chesapeake Bay and Sensitive Watersheds within the Commonwealth of Virginia, report prepared for the Chesapeake Bay Foundation (August 2009).
[27] For further details, see Scire, *et al*., A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech, Inc., Concord, MA, 2000. http://src.com/calpuff/download/CALPUFF_UsersGuide.pdf
[28] Including SO_2 and sulfate in the CALPUFF modeling was necessary to provide the appropriate balance between nitric acid and nitrate formation.

Table 3. CALPUFF Model Results: Annual Nitrogen Deposition due to the Wheelabrator Facility

Receptor Area	Annual Nitrogen Deposition (kg/yr)
Chesapeake Bay Watershed	42,719
Chesapeake Bay	2,171
Maryland	18,585
Virginia	9,361
Pennsylvania	23,185
James River Basin Watershed	1,911

The annual deposition of nitrogen to the Chesapeake Bay Watershed due to Wheelabrator's emissions was estimated by the CALPUFF model to be almost 43 metric tons, which equates to more than 117 kg of nitrogen deposition each day. The estimated 43 metric tons of nitrogen deposited within the Chesapeake Bay Watershed accounts for about 14 percent of Wheelabrator's annual nitrogen emissions (emitted as NO_X).

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Figure 8. Huntington Park Beach on the James River

APPENDIX A: AERMOD Modeling Results

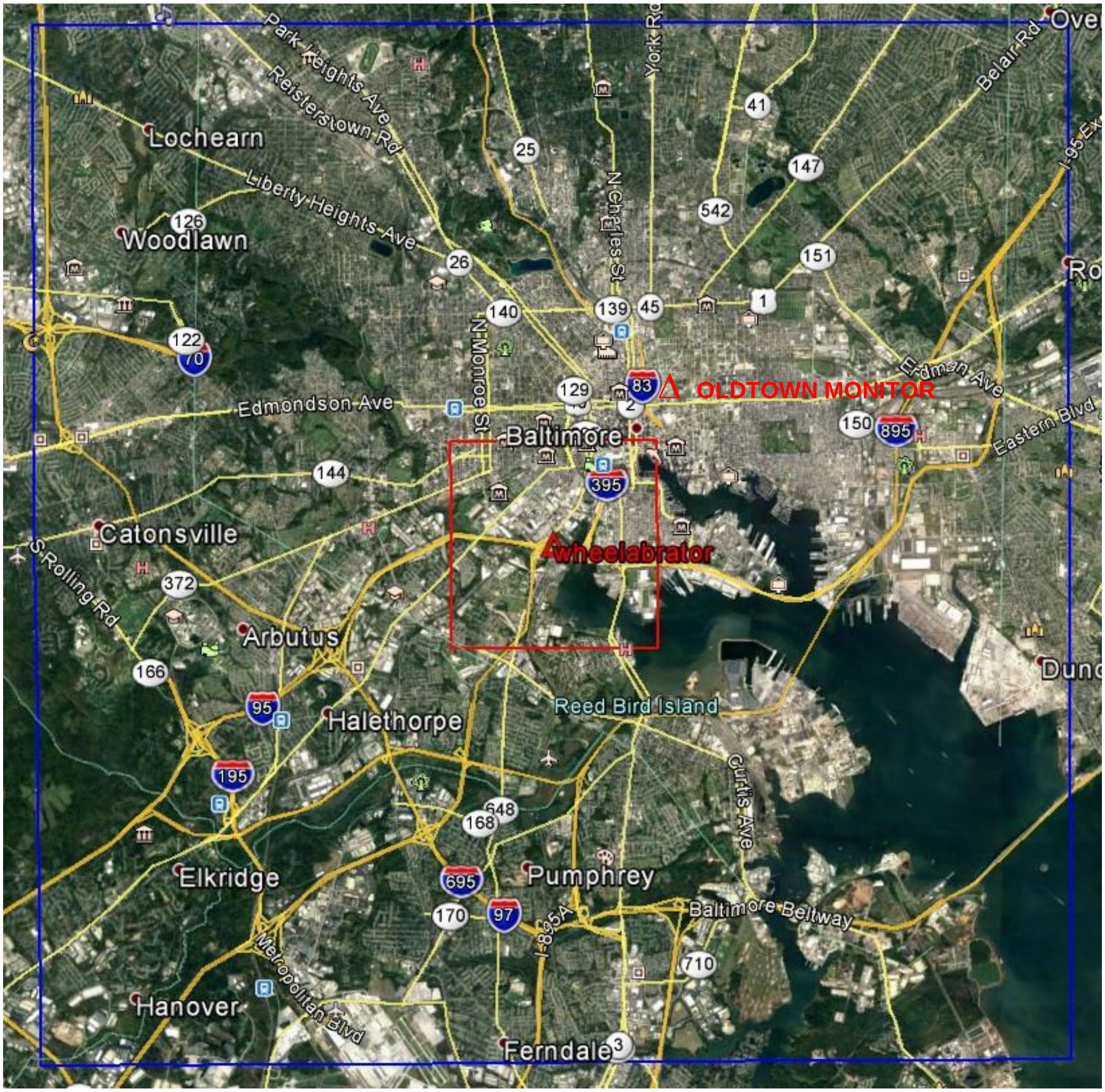


Figure A.1. Fine grid (red; 4x4 km) and coarse grid (blue: 20x20 km)

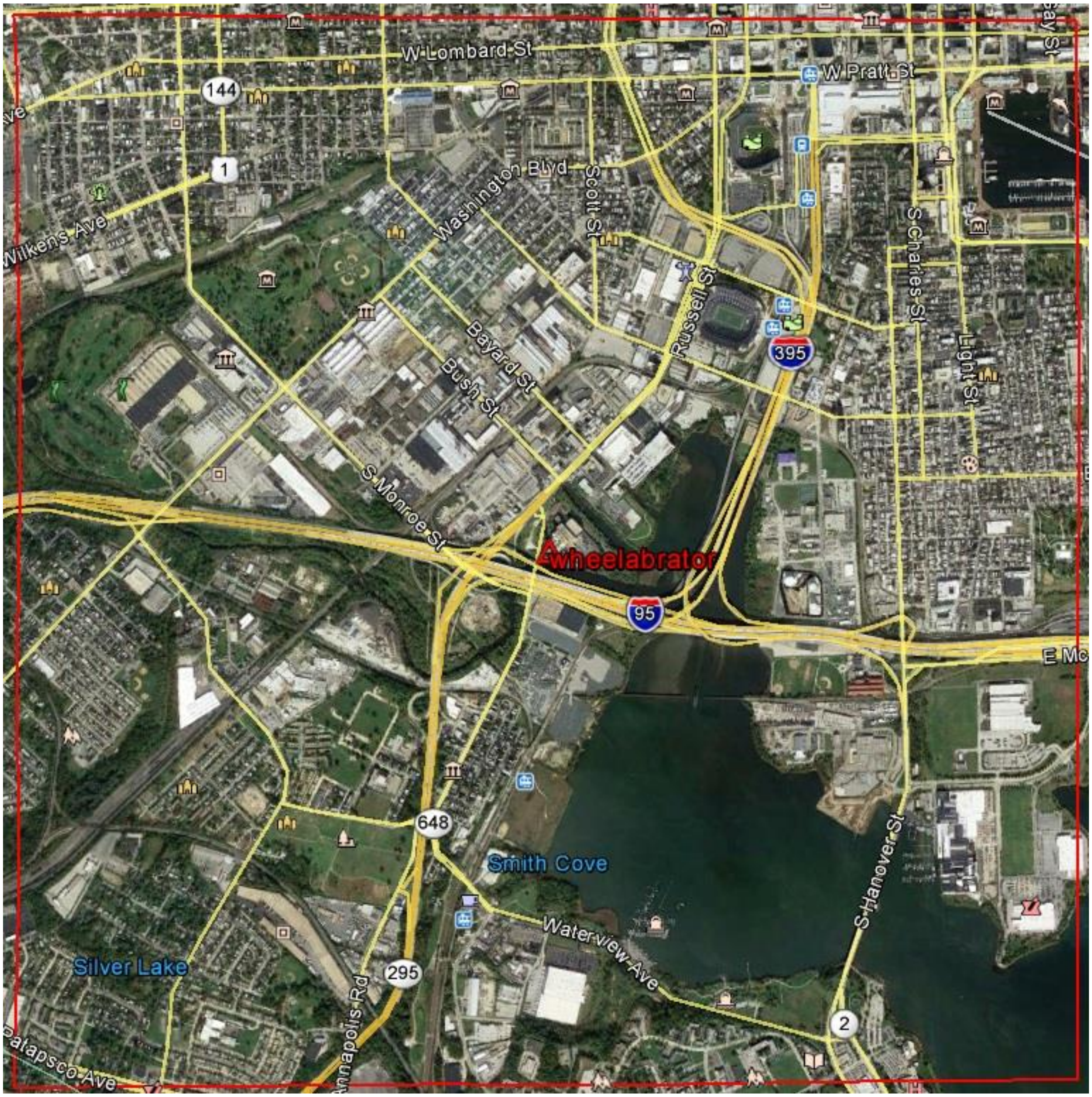


Figure A.2. Fine grid (4x4 km)

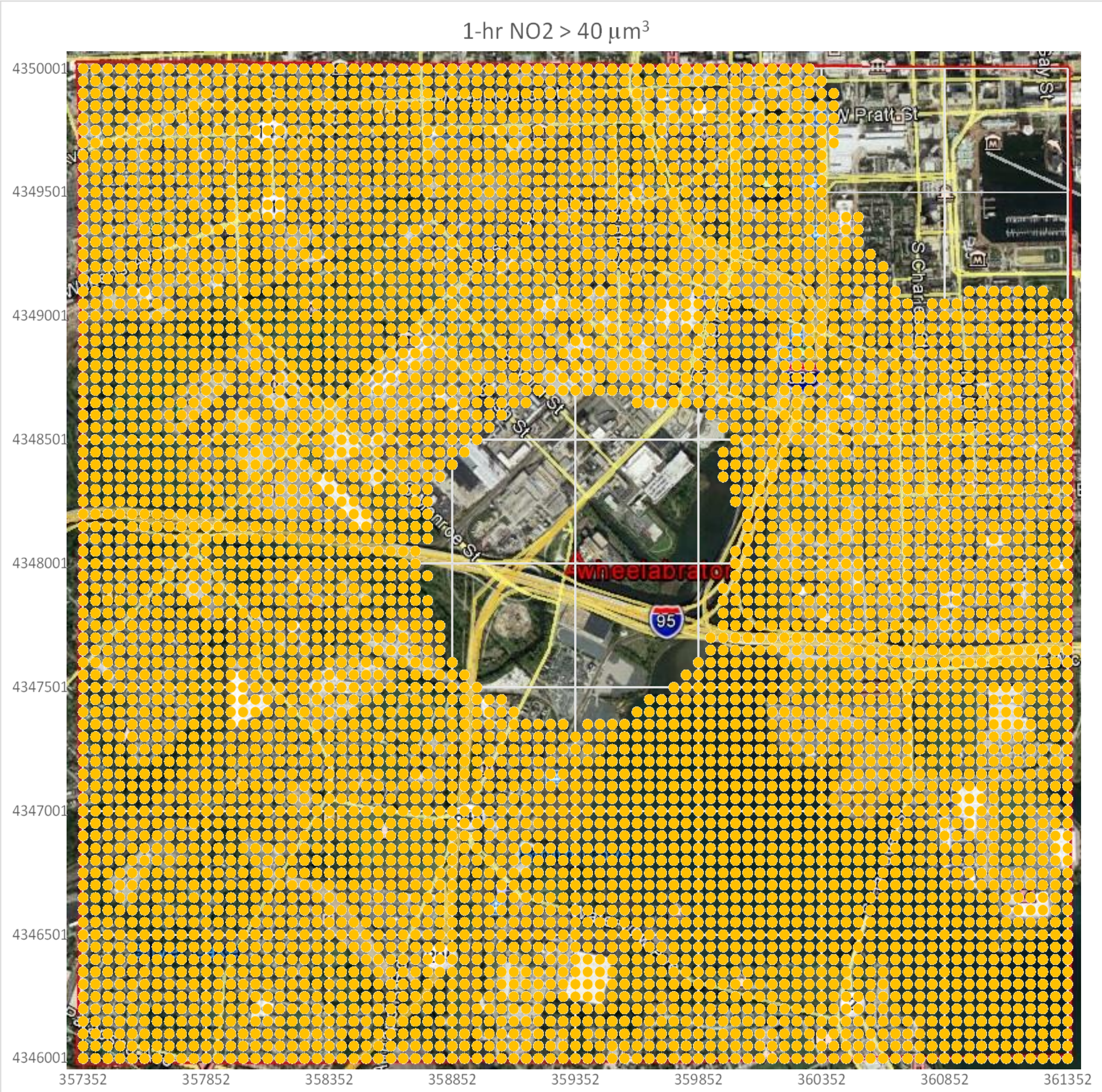


Figure A.3 Fine grid: modeled max 1-hr-NO_2 concentrations exceeding 40 µg/m^3

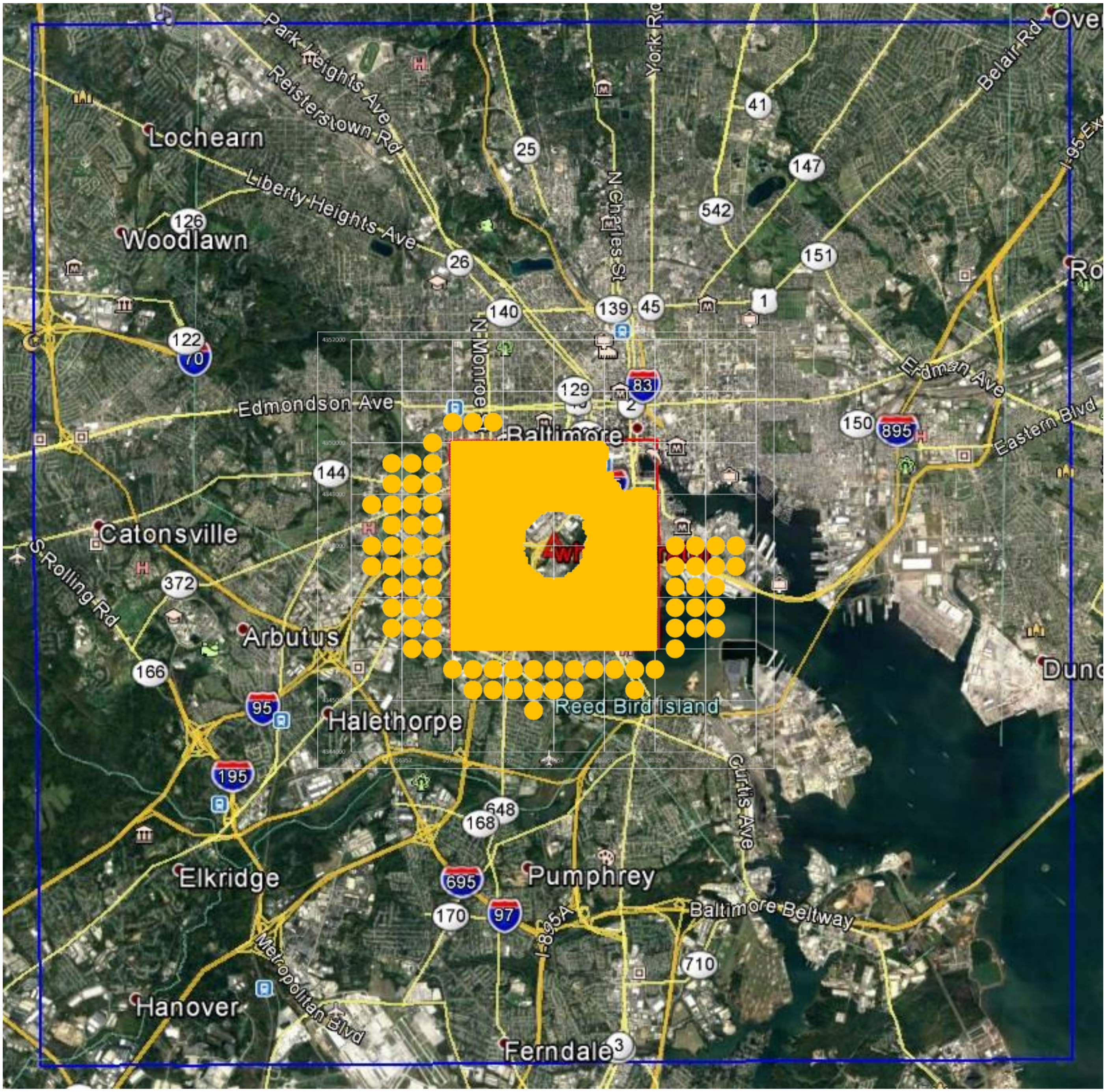


Figure A.4. Fine and coarse grids: modeled max 1-hr-NO_2 concentrations exceeding 40 $\mu g/m^3$

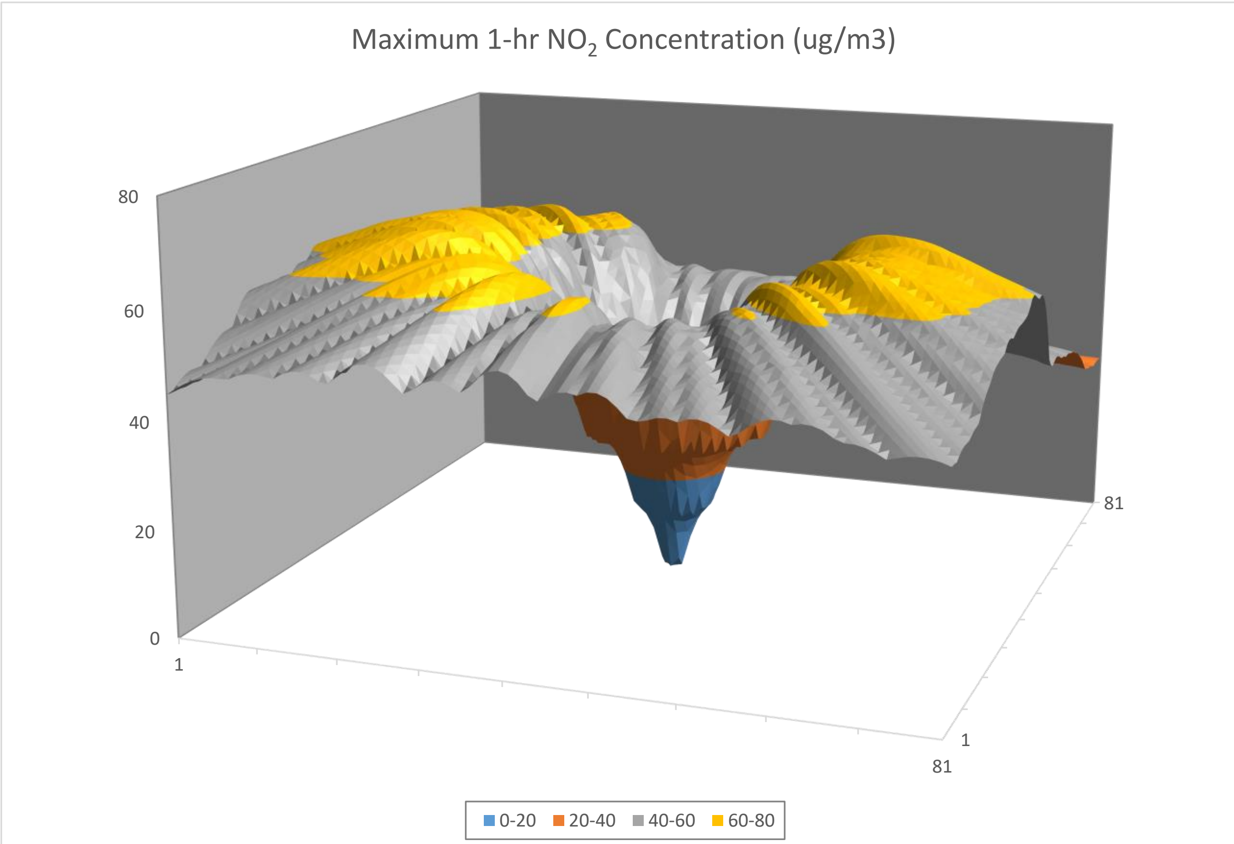
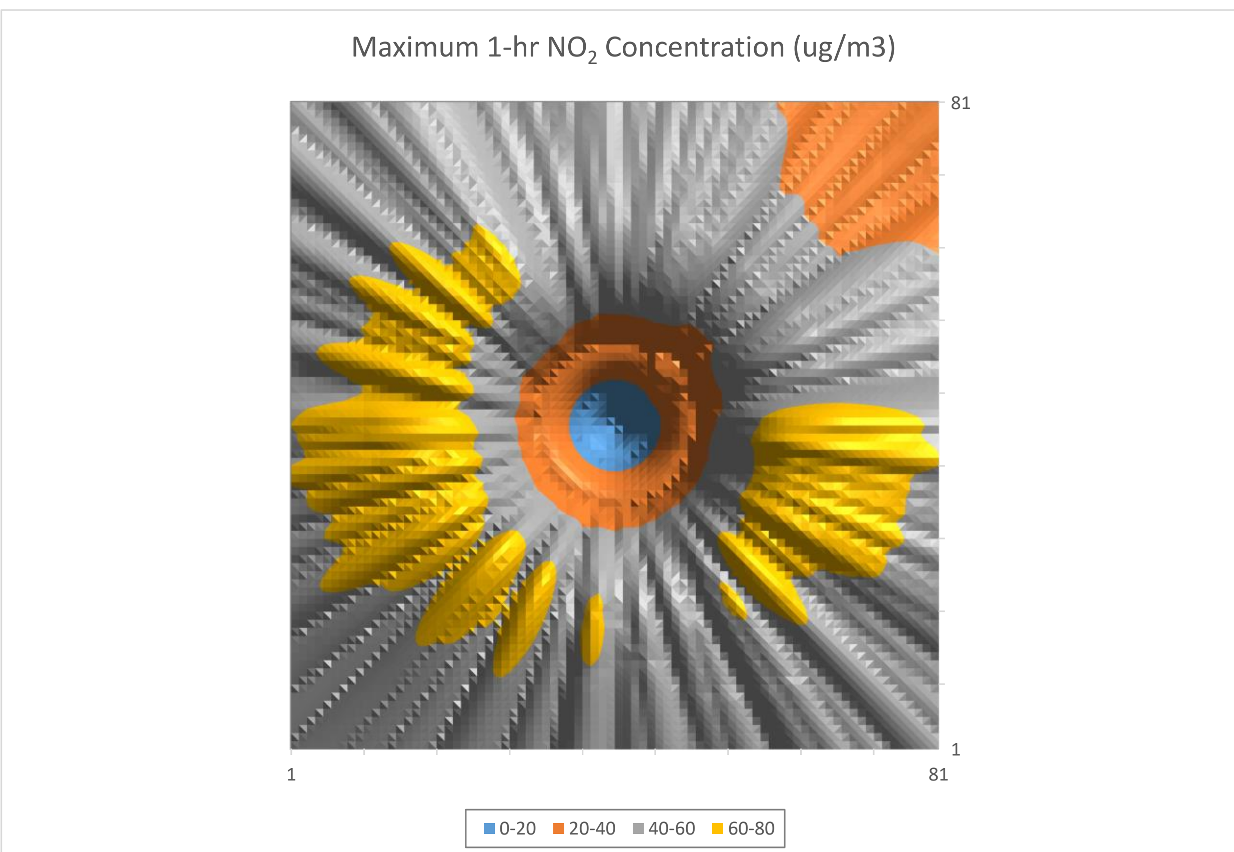


Figure A.5(a and b). Fine grid: modeled maximum 1-hr-NO_2 concentrations



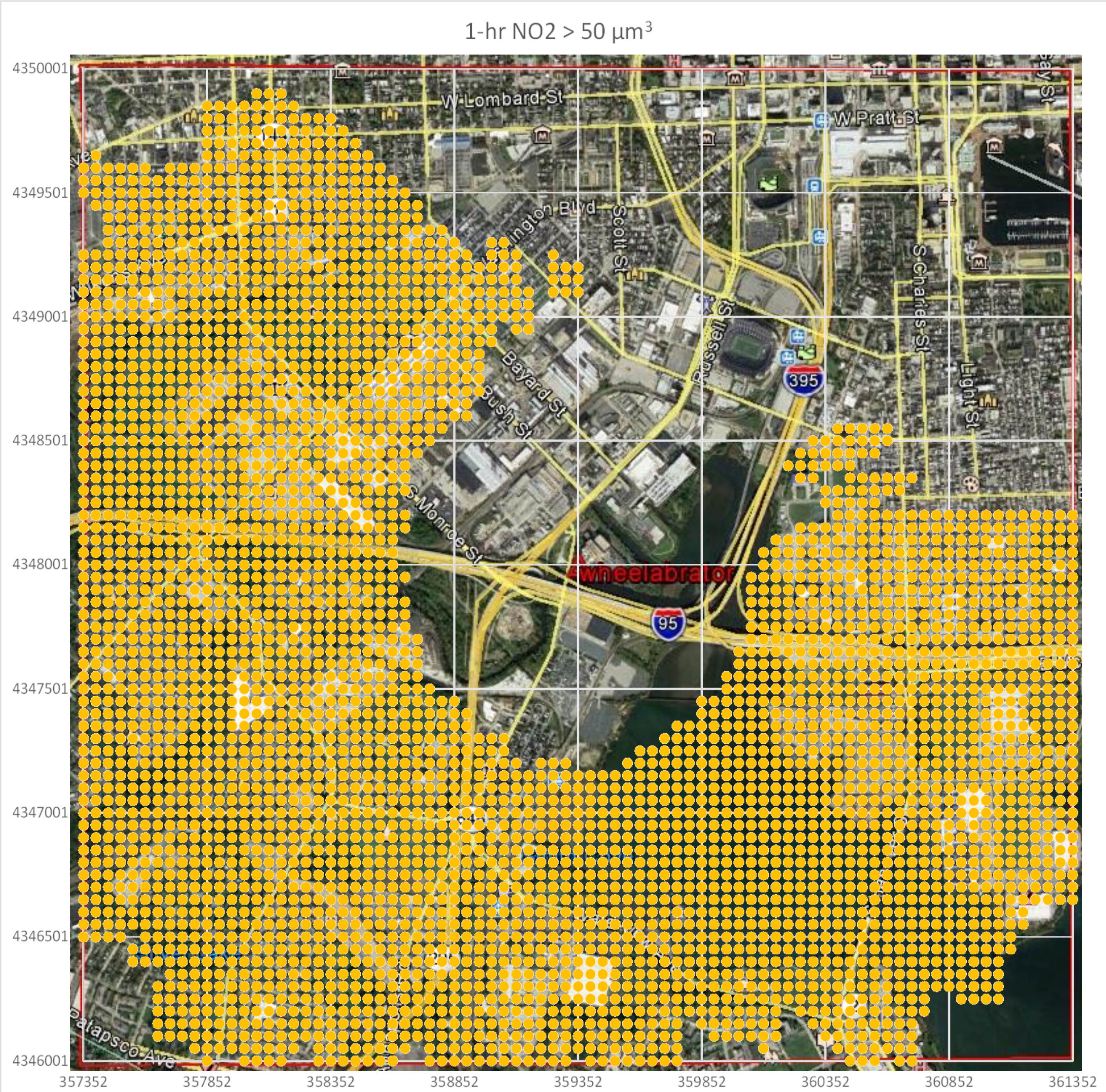


Figure A.6. Fine grid: modeled max 1-hr-NO_2 concentrations exceeding 50 µg/m^3

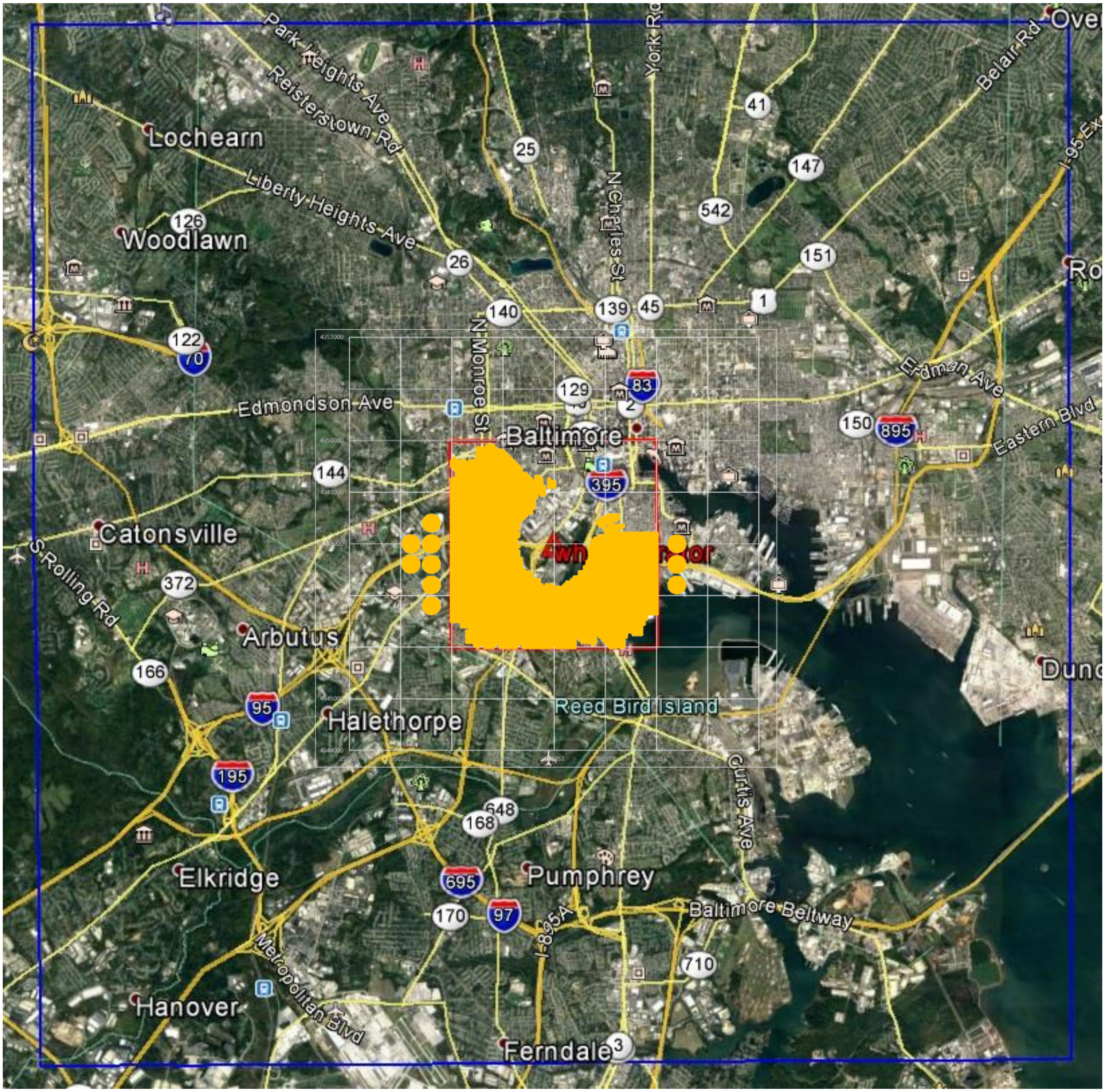


Figure A.7 Fine and coarse grids: modeled max 1-hr-NO_2 concentrations exceeding 50 µg/m^3

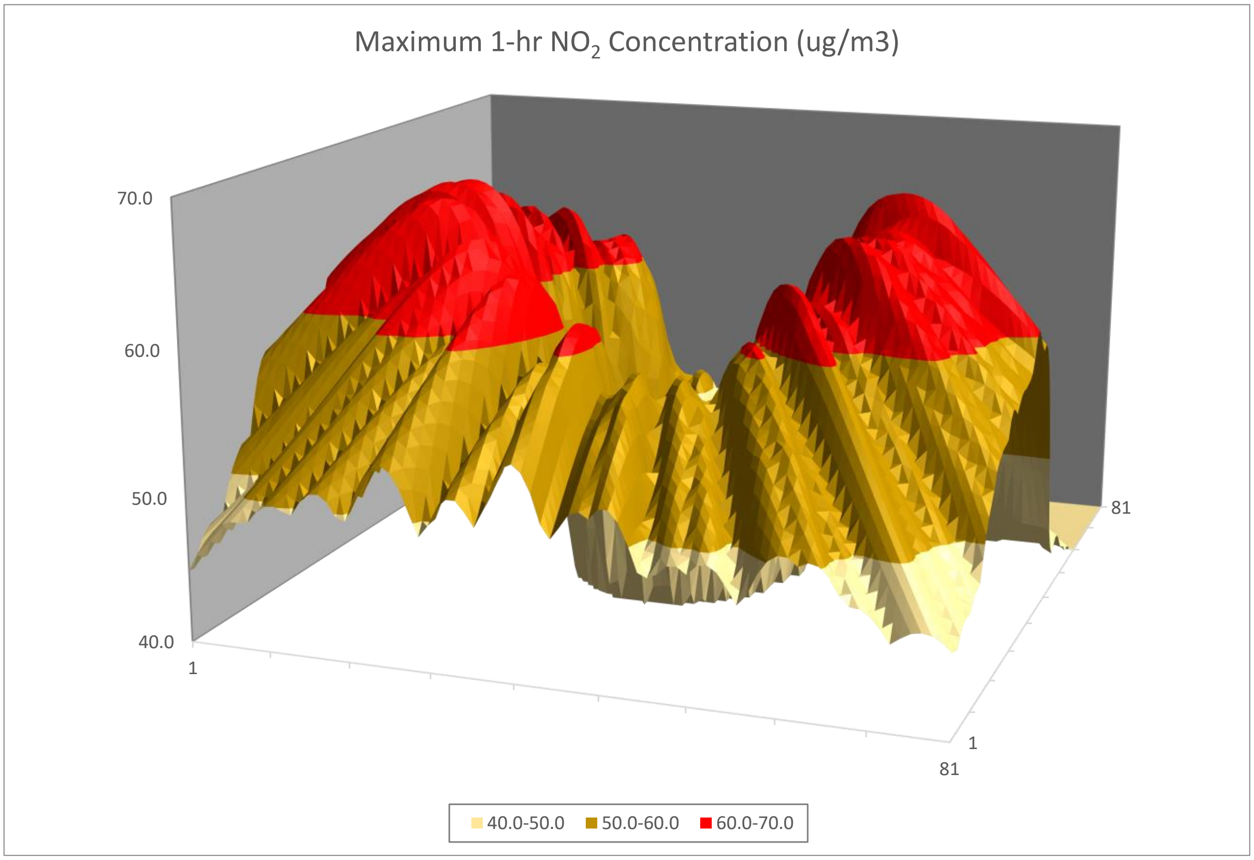
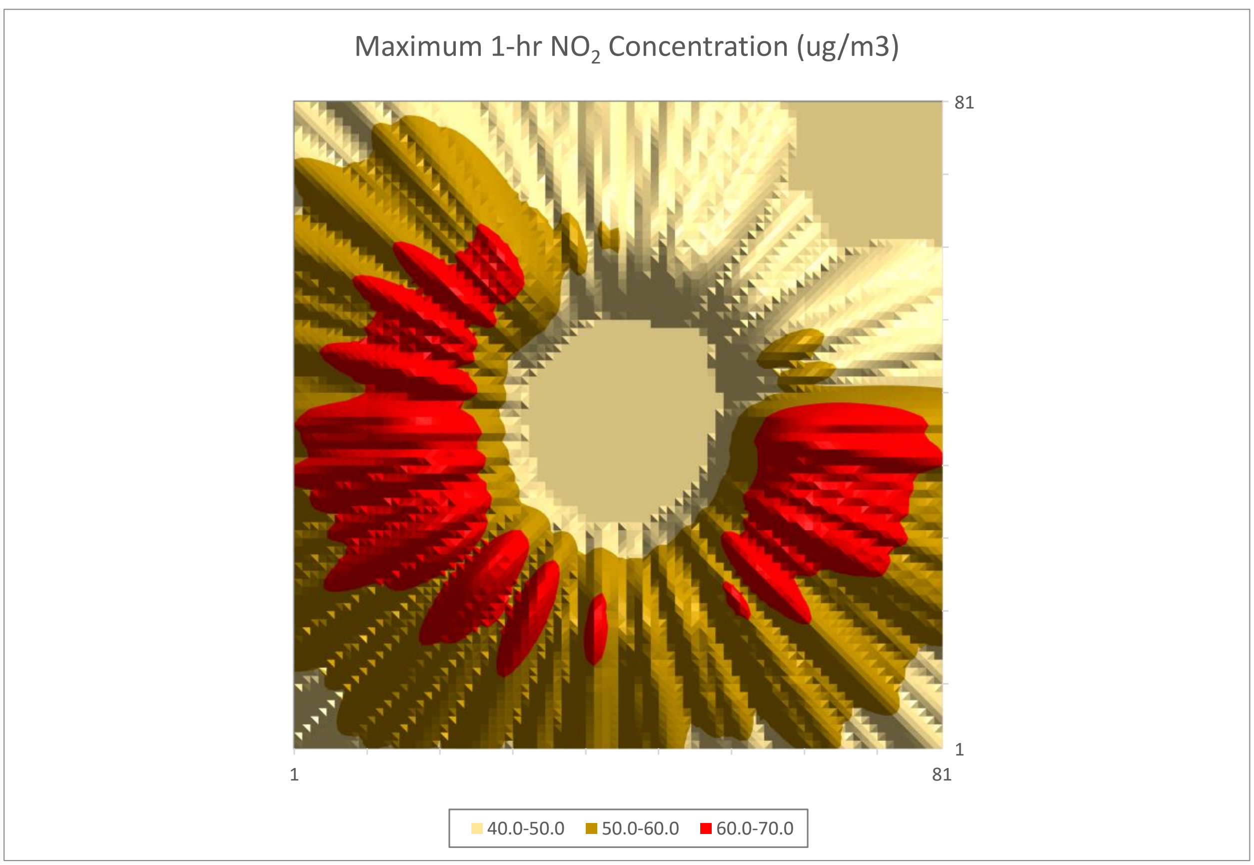


Figure A.8(a and b). Fine grid: modeled maximum 1-hr-NO_2 concentrations



ATTACHMENT B

EXPERT REPORT

On

NOx Emissions from the Wheelabrator Baltimore Municipal Waste Incinerator in Baltimore City, owned and operated by Wheelabrator Baltimore, L.P. ("Wheelabrator")

By

Dr. Ranajit (Ron) Sahu, Consultant[1]

May 5, 2017

I have prepared this report based on my review of the documents provided by the Maryland Department of the Environment (MDE), a telephone discussion held with MDE staff, and all of the publicly available materials relating to NOx emissions from the three incinerator boilers at the Wheelabrator facility. I have carefully reviewed Wheelabrator's suggestion regarding what the NOx RACT limit should be for these boilers and I have also carefully reviewed the NOx optimization and other studies that have been conducted by Wheelabrator since mid-2016 for which only partial and incomplete information is available. Lastly, I have carefully reviewed MDE discussions regarding RACT for this facility based on a review of various e-mails, both internal to MDE as well as between MDE and Wheelabrator.

Based on all of this, my observations are as follows.

<u>Data Gaps for Understanding NOx Generation</u>

The available information regarding NOx emissions generation and subsequent control at each of the three Wheelabrator boilers is incomplete due to the presence of significant data gaps. Notwithstanding the passage of time over which this issue has been under study and review by both the MDE and Wheelabrator, it is nonetheless clear that fundamental data gaps remain with regards to NOx generation and control, and therefore the resultant NOx emissions – which ultimately affect how the level corresponding to RACT should be determined.[2] The following are the more noteworthy data gaps:

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[1] Resume available upon request.

[2] For the purposes of this discussion, we will assume that the form of the NOx RACT standard will be X ppm at 7% oxygen in the exhaust flue gas that is emitted from the atmosphere. I will further assume that the standard includes a 24-hour averaging period. I do not necessarily agree with either of these as being the proper form of the RACT standard, even though I recognize that other jurisdictions have used NOx emission standards from incinerators along similar lines. At least two states, New Hampshire and Pennsylvania, use a mass-based standard (lb/MMBtu). *See* Ozone Transport Commission, White Paper on Control Technologies and OTC State Regulations for Nitrogen Oxides (NOx) Emissions from Eight Source Categories, at Appendix D: Municipal Waste Combustors in Ozone Transport Region (Feb. 10, 2017), http://www.otcair.org/upload/Documents/Reports/OTC_White_Paper_NOx_Controls_Regs_Eight_Sources_Final_Draft_02152017.pdf.

(a) Almost nothing is known about the nitrogen content of the waste that is burned at the incinerators. Given that the relatively low temperature combustion process used in the incinerators (in contrast to say, the temperatures in a coal-fired boiler), substantial portions of the NOx generated at the combustion process itself are by the so-called fuel-NOx pathway, as opposed to the more common thermal-NOx pathway in higher temperature processes. It is likely that a disproportionate amount of the NOx generated in the boilers is due to the combustion of that portion of the waste which is relatively high in nitrogen. Without understanding this NOx generation step in greater detail, it is improper to simply focus on the probable or possible NOx control options. Thus, MDE must require better characterization of the chemical composition of the waste fuel – especially with regards to its nitrogen content, including the forms of nitrogen present in the fuels. Since little is available in the record regarding fuel composition and nitrogen content, the MDE should require that representative samples of the fuel be analyzed and the results be made available to the public.

(b) Similar to the above, almost nothing is known about other fuel composition aspects, such as its as-burned moisture content and its oxygen content, which can affect the NOx generation levels at the furnace grate. Like the request above, I ask that the MDE require complete and representative analyses of these additional compositional parameters of the fuel as well.

(c) A detailed description of the combustion process, in particular the air-fuel ratio management that occurs at the furnace grate – as the fuel travels through the furnace – is not available in the public record. Wheelabrator should provide far more detail to describe how it controls the combustion process and what the critical control parameters are. What are the target set-points for these critical parameters so that one can understand the trade-offs being made in combustion controls at Wheelabrator? How does the operator decide to modulate the air fuel ratio across the grate and above the combustion zone – i.e., based on what parametric feedback?

All of the above is essential to understand the NOx generation step in each boiler and to identify the key parameters that affect the generation of NOx at the combustion grate itself or its immediate vicinity.

Issues with the Optimization Study

Wheelabrator conducted a short optimization study ("Quinapoxet Study" or "optimization study") of its existing Selective Non-Catalytic Reduction (SNCR) NOx control system in order to improve the NOx control capability of that system from its current performance. I have reviewed the Quinapoxet Study report, "Final Report NOx Control System Optimization at the Wheelabrator Baltimore WTE Facility, Quinapoxet Solutions, (undated, 2016)." The review, however, raised

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It would be much more preferable to have a mass-based (and not a concentration-based) standard along the lines of X lbs. NOx/ton trash burned. With regards to the averaging time, while a 24-hour standard has its uses, a secondary standard limiting NOx emissions over a shorter time period, such as one hour, is also desirable – both to conform the RACT standard to short-term NAAQS for NOx and also to put the onus on the operator, Wheelabrator, to address both average as well as peak NOx emissions.

numerous questions that need to be addressed to allow for a better understanding of the findings of that study and to assess its usefulness. I address some of the issues below.

It is not clear how flows inside the furnaces and flow distributions were measured during the study. The report states that "it was confirmed that furnace gas flows favored the rear wall at the urea injection level." But the basis for this statement is not clear. Relatedly, the support for Figure 6, "Typical Boiler Furnace Flow," is not clear.

To the extent that computational fluid dynamics (CFD) modeling or similar flow testing has been done on the boilers, there is no publicly available documentation. If no CFD modeling has been conducted at each boiler (since the optimization study confirms fairly distinct boiler to boiler variations in NOx emission rates), then Wheelabrator should be asked to do such modeling. It is simply premature to attempt to "optimize" NOx emissions from such boilers without a basic understanding of NOx generation and distribution as well as the effect of SNCR, which can only be obtained from properly conducted CFD modeling analyses.

The Quinapoxet Study report does not discuss any temperature profiling vertically in either boiler #1 or #2. It is not clear if any vertical temperature profiling was done at either of these boilers as part of the optimization study or otherwise. This is a critical issue. It is not clear how the plane at which the SNCR reagent is being injected could have been determined without doing such vertical temperature profiling.

In some of the discussions leading up to the optimization study, Wheelabrator identified, rightly so, that gallons/mass of urea injection was an important variable and they wanted to increase the mixing of the urea and gases, and the relevant variables are droplet size and droplet size distribution. In a later version, the focus is on injection pressure and dilution of water, but not segregated in gallons per hour, and there are no further discussions on droplet size or droplet size distribution. The final study report does not report the injection pressure, droplet size distribution, or similar important variables that directly affect urea/gas mixing. Thus, the degree to which gas/urea mixing was improved during the optimization study is unclear.

The study report indicates that gas temperature measurements were obtained using the GasTemp instrument. However, GasTemp does not provide a spatially resolved measurement because it provides a line-of-sight integrated measurement. It is not clear, therefore, why this path-integrated temperature measurement would be more useful when the goal should be to obtain the spatial temperature mapping inside the boiler.

These and several additional questions pertaining to the Quinapoxet Study were submitted to the MDE on April 4, 2017 and are enclosed here as Attachment C.

Ammonia Slip

One of the drawbacks for using SNCR as a NOx control strategy is the likelihood (or almost certainty) that there will be a significant amount of excess ammonia, which would result in a consequently large amount of "ammonia slip" emissions into the ambient from the stack. In addition to the obvious waste of resources, this slip is undesirable given that ammonia is a toxic air compound. Regardless of the point I will make next regarding considering hybrid SNCR/SCR as a NOx control measure – which would reduce ammonia slip – MDE should regulate the amount of ammonia allowed to be emitted as slip. MDE's position on the lack of such a limit and/or how compliance with such a limit can be assessed is confusing. In discussions with MDE staff, it appears that there is some confusion regarding the ability to continuously measure ammonia at the stack. I note that ammonia CEMS are widely available.[3] I also note that EPA's performance specification for ammonia CEMS dates back to 2004.[4]

Hybrid SNCR/SCR as a NOx Control Option

It is clear from discussions with the MDE staff that neither the MDE nor Wheelabrator has evaluated whether a hybrid combination of SNCR followed by one or more layers of SCR catalyst placed at the appropriate locations in the current gas path (i.e., where the temperatures are proper for the SCR reactions to take place) can work at the Wheelabrator boilers.

Given the significant NOx emissions from Wheelabrator (well over 1,000 tons/year) and given the very modest reductions in NOx that are under consideration via optimization of the existing SNCR control (in the range of around 100 tons/year or even less), I believe that a thorough technical feasibility evaluation of the hybrid SNCR/SCR option is worthwhile. The advantage of such systems is that the opportunistically placed in-duct SCR catalyst can take advantage of the ammonia/urea slip from the SNCR and effect significant additional NOx reductions (i.e., around 50-75%) in the catalyst layer(s), leading to substantially lower NOx at the stack than SNCR alone. Of course, as mentioned above, utilizing the ammonia slip from the SNCR in the downstream SCR will also reduce ammonia emissions to the atmosphere as well. The cost of placing the SCR catalyst within the duct is typically far lower than installing a stand-alone SCR system. Of course, engineering evaluations to assess the feasibility of a hybrid SNCR/SCR system need to be done before rejecting this approach. I encourage MDE to require Wheelabrator to do so. As I note, if this system is technically feasible, its cost would be far lower than a SCR system and NOx reductions would be significant (i.e., 50-75%) as opposed to the 10% or so NOx reduction under consideration as RACT for these boilers.

It is important to note that the SCR catalyst does not particularly care where the NOx originates from – it only acts on the local gas composition, which should be fully known and characterized at the current boilers. Thus, it is moot whether such hybrid systems have been used at other incinerators or not. To date, they have mostly been used at coal-fired boilers – which are fairly challenging applications. As examples and background, I am providing two Exhibits (from two different vendors) relating to hybrid SNCR/SCR systems.

[3] See, for example, http://www.horiba.com/us/en/process-environmental/products/combustion/cems-stack-gas-emission/details/stack-gas-analyzer-enda-7000-series-23329/.

[4] https://www3.epa.gov/ttn/emc/prelim/pps-001.pdf

RACT Statistical Calculations

In my review of the documents provided by MDE, I saw that Wheelabrator has used a "MACT-type" 99 percentile upper confidence level (UCL) to arrive at what it believes should be the appropriate RACT NOx level for the Wheelabrator incinerators. However, this raises two issues.

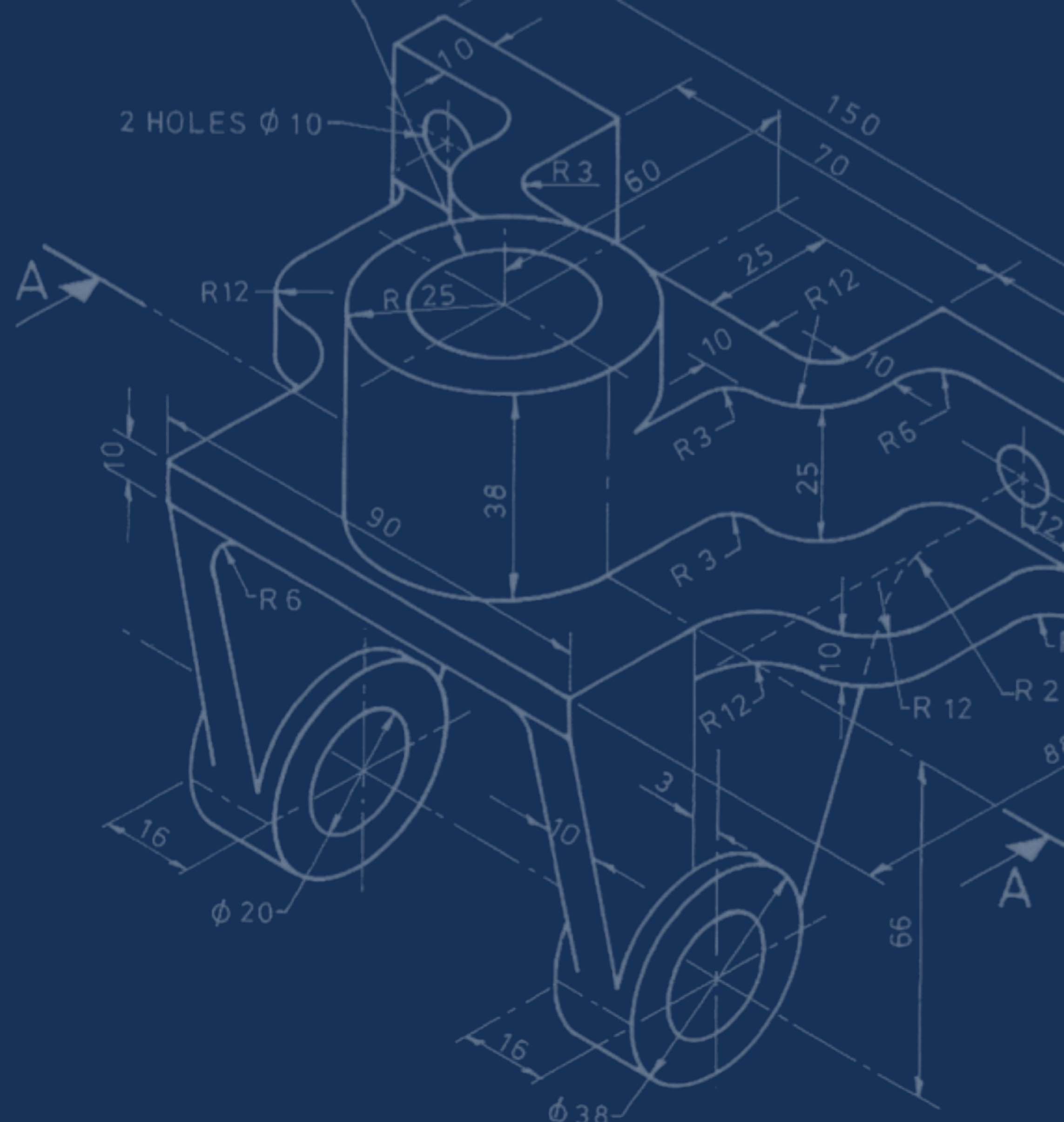
First, the actual NOx dataset which was used by Wheelabrator to conduct the statistical computations is not publicly available. Without this, it is not clear whether only the NOx data collected from the short-term Quinapoxet Study were included or if additional NOx data collected by Wheelabrator since that Study were also included (or should be included).

Second, from a policy standpoint it is not clear whether the MDE should be bound by the statistical approach suggested by Wheelabrator. MDE should provide a proper rationale for the statistical (or other) basis that will be used to determine NOx RACT for the Wheelabrator boilers. In doing so, MDE should address the form of the RACT limit, i.e., the issue raised earlier in footnote 2 in this report.

EXHIBITS 1 & 2 – HYBRID SNCR/SCR

Hybrid DeNOx

A Cost-Effective NOx Reduction Solution for Small & Medium Boilers



George Grgich, VP of Sales
george.grgich@lpamina.com

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LP AMINA WAS ESTABLISHED WITH A MISSION TO SERVE AS AN INTEGRATED PLATFORM TO DEVELOP AND DEPLOY CLEAN COAL SOLUTIONS GLOBALLY

125+
Full time employees, on 3 continents

8
Locations worldwide, with activities in the US, Europe and Asia

10+
Patents, focused on coal / biomass conversion and pollution control

40+
Projects completed in last 5 years

15
Provinces and municipalities in China served to date

10GW
Of power plants retrofitted with pollution controls

Strategic partnership with Bayer to develop coal utilization technologies

The State of Wyoming co-funded LP Amina's Coal to Chemicals technology

West Virginia University participates in the research of LP Amina's CtC technology

LP Amina is a founding member and co-chair of the US-China Energy Cooperation Program (ECP)

LP Amina is a founding member of the US-China Clean Energy Research Center (CERC)

LP AMINA OFFERS A RANGE OF SOLUTIONS FOCUSED ON NOx REDUCTION FOR COAL AND GAS POWER AS WELL AS ADVANCED COAL UTILIZATION (COAL TO CHEMICALS)

Low NOx Burners

Shajiao Power Plant, Shenzhen

- LP Amina is **market leader** in pre-combustion De-NOx solutions via in-furnace optimization in China
- **25+ Projects** at major Chinese clients including China Huaneng Group, Guangzhou Yuedian Group, Datang Group

Hybrid LNB/SNCR/SCR

Yixing Power, Jiangsu

- **Proprietary technology** developed by LP Amina
- Combines benefits of several De-NOx technologies and brings **superior De-NOx** results at affordable price
- Installed at multiple units at Yixing Power in Jiangsu with **80% NOx reduction**

Direct Injection SCR

Jingfeng Power, Beijing

- **Proprietary technology** developed by LP Amina
- LP Amina was able to reduce NOx by **over 80%** with slip below 2 ppm
- More efficient, direct injection SCR uses significantly **less energy** and is cheaper to build

Advanced Coal Tech.

Hepo Facility, Shanxi

- Innovative process to **co-produce** electric power and high-value chemicals
- Extraordinary **economics** and **environmental im-pact improvement** from systems perspective
- Piloted in Shanxi, China; to be fully operational Q4 ‘14

LP AMINA'S PROPRIETARY DE-NOX HYBRID: COMBINES BENEFITS OF LNB, SNCR, AND SCR TECHNOLOGIES TO BRING SUPERIOR DE-NOX RESULTS AT AFFORDABLE PRICE

Average NOx Reduction by Each Technology (%)

SNCR 25+% — *Relatively low upfront cost, but ongoing operating costs (ammonia)*

LNB 45+% — *Medium CapEx, no operating costs, but in many cases not enough to meet the standard. Requires boiler retrofit know-how.*

SCR 80+% — *Most effective De-NOx solution, but also the most expensive due to the cost of catalyst*

Gradual NOx Reduction in LP Amina's Hybrid Approach (%)

LNB 45% — *Initial NOx reduction through proprietary retrofit of burner and SOFA ports*

SNCR +15% — *Further NOx reduction through SNCR*

SCR +20% — *Final NOx reduction through in-duct SCR*

80%+

The core idea behind LP Amina's Hybrid De-NOx Technology is to combine strengths of LNB, SNCR and SCR technologies, leveraging relative advantages of each

LP AMINA'S FIRST HYBRID TECHNOLOGY WAS INSTALLED ON YIXING UNION'S UNITS 5/6 IN CHINA'S JIANGSU PROVINCE, TOTAL 80% OF THE NOX REDUCTION WAS ACHIEVED

Yixing Union Units 5 and 6 Project Overview

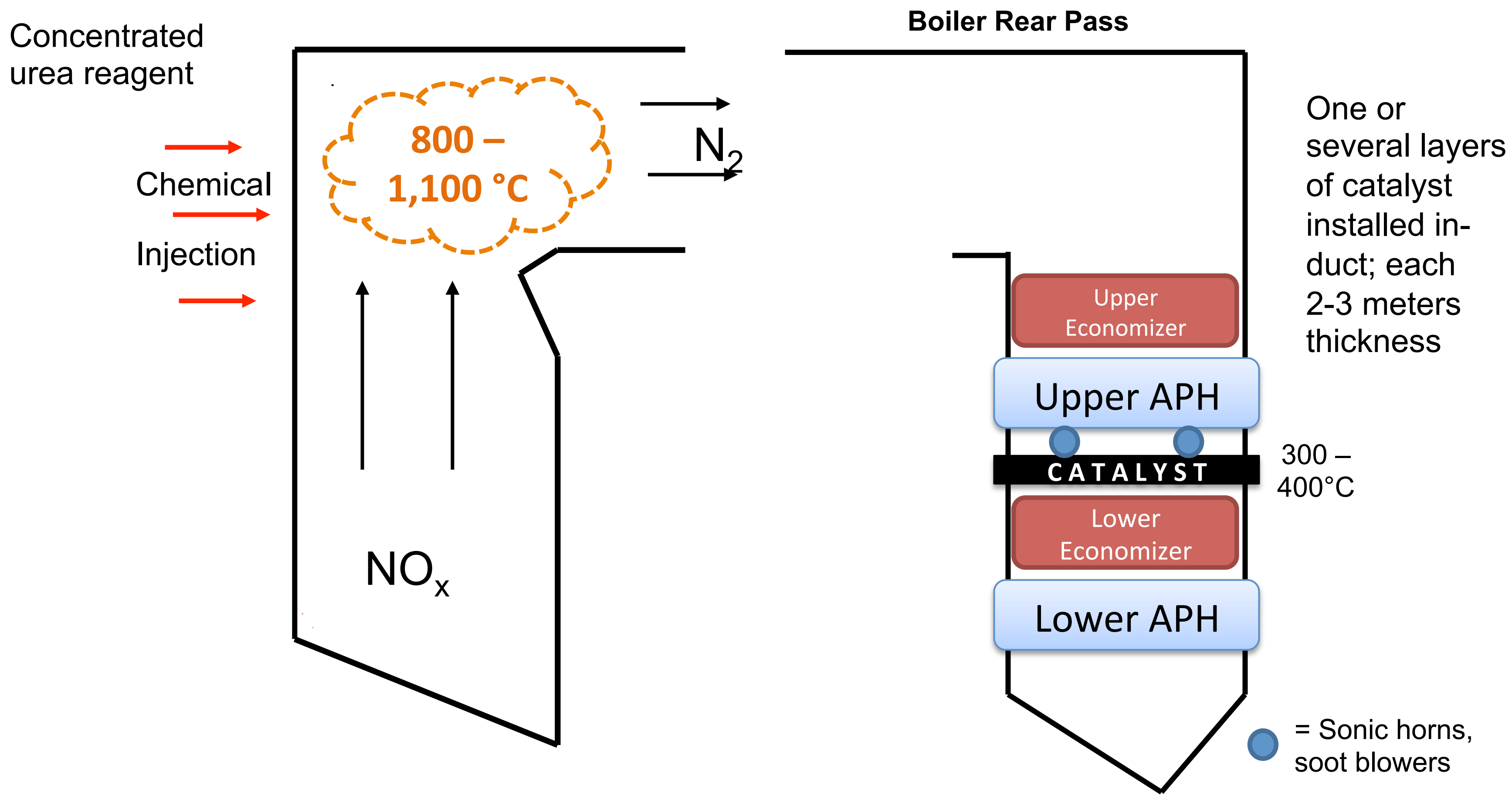
Units Overview:
- Power generation capacity: 2 x 50 MW
- Combustion type: T-Fired
- Fuel: Bituminous coal

Scope:
- SOFA and Low NOx Firing Systems
- Proprietary SNCR/SCR Hybrid
- Patented coal classifiers

Results:
- NOx reduced from 0.44 to 0.08 lb/MMBTu
- LOI below 1.5%
- Expanded fuel flexibility
- Increased unit efficiency
- Significant cost reduction due to the large savings in ammonia and catalysts
- Currently working on few more units for Yixing

IN HYBRID ARRANGEMENT, AMMONIA INJECTORS ARE INSTALLED IN UPPER FURNACE, AND ONE (OR MORE) IN-DUCT CATALYST INSTALLED IN BOILER REAR PASS

Schematical Arrangement of In-Duct SNCR & SCR



IN HYBRID ARRANGEMENT, AMMONIA INJECTORS ARE INSTALLED IN UPPER FURNACE, AND ONE (OR MORE) IN-DUCT CATALYST INSTALLED IN BOILER REAR PASS

Advantages

- Can achieve **significant NOx reduction**, especially when combined with LNB
- **Lower capital** cost than SCR (smaller catalyst volume, installed in-duct)
- **No significant slip** issues because catalyst cleans up excess ammonia

Constraints

- Boilers require adequate **in-duct space** for catalyst installation
- Requires **EPC with know-how** of all three technologies: LNB, SNCR, SCR

Applicability

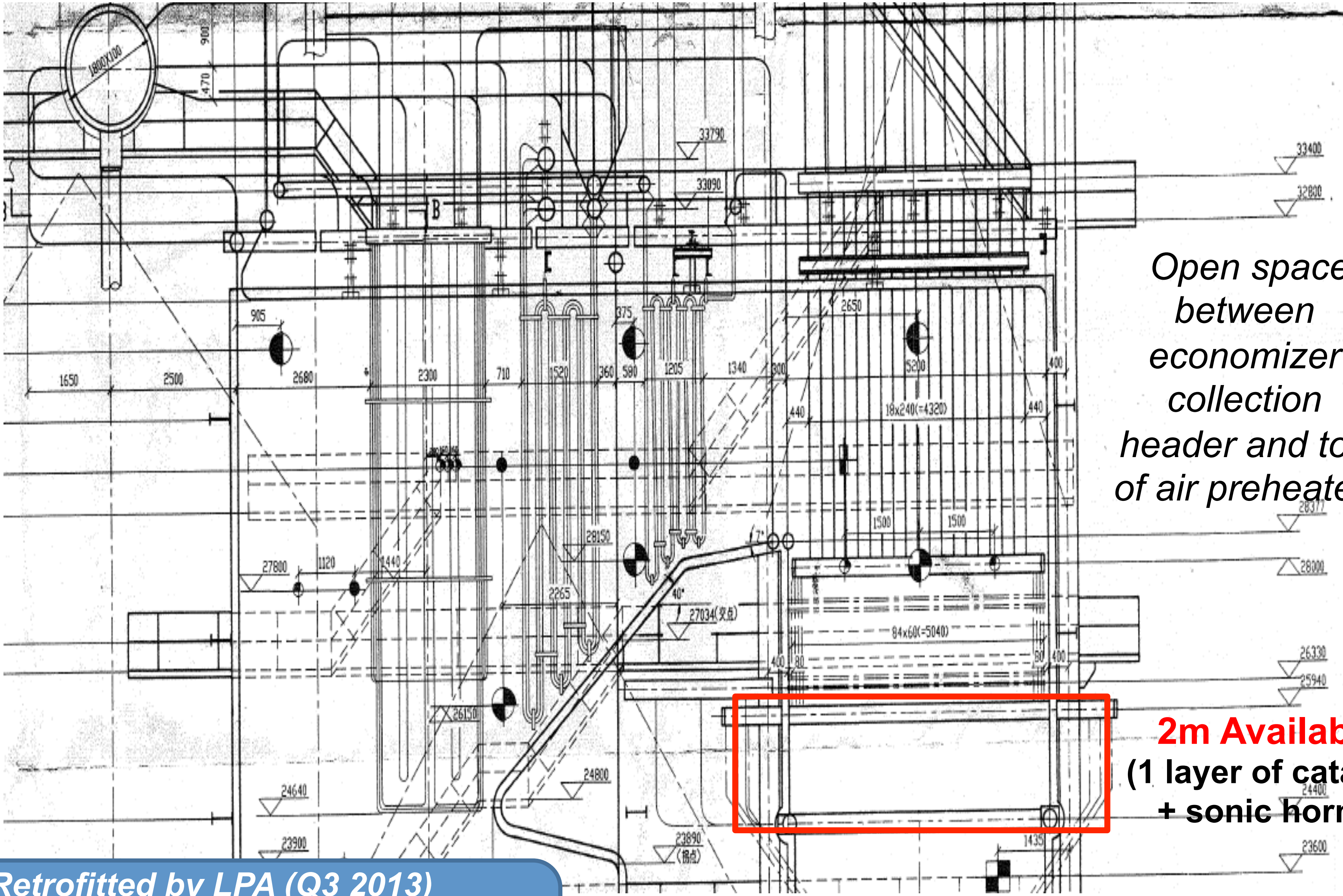
Small Units

Medium Units (50-300 MW)

- Smaller units utilize LNB and (S)OFA, *but still need additional NOx reduction*
  - SCR too expensive/ too large for some units
  - SNCR might not provide effective NOx reduction without large amount of slip

Large Units

- LNB
- SCR



Open space between economizer collection header and top of air preheater.

2m Available

(1 layer of catalyst + sonic horns)

Retrofitted by LPA (Q3 2013)

LNB **–** 40% reduction (200 mg/Nm³)

SNCR – 30% reduction (200 mg/Nm³)

SCR – 50% reduction (100 mg/Nm³)

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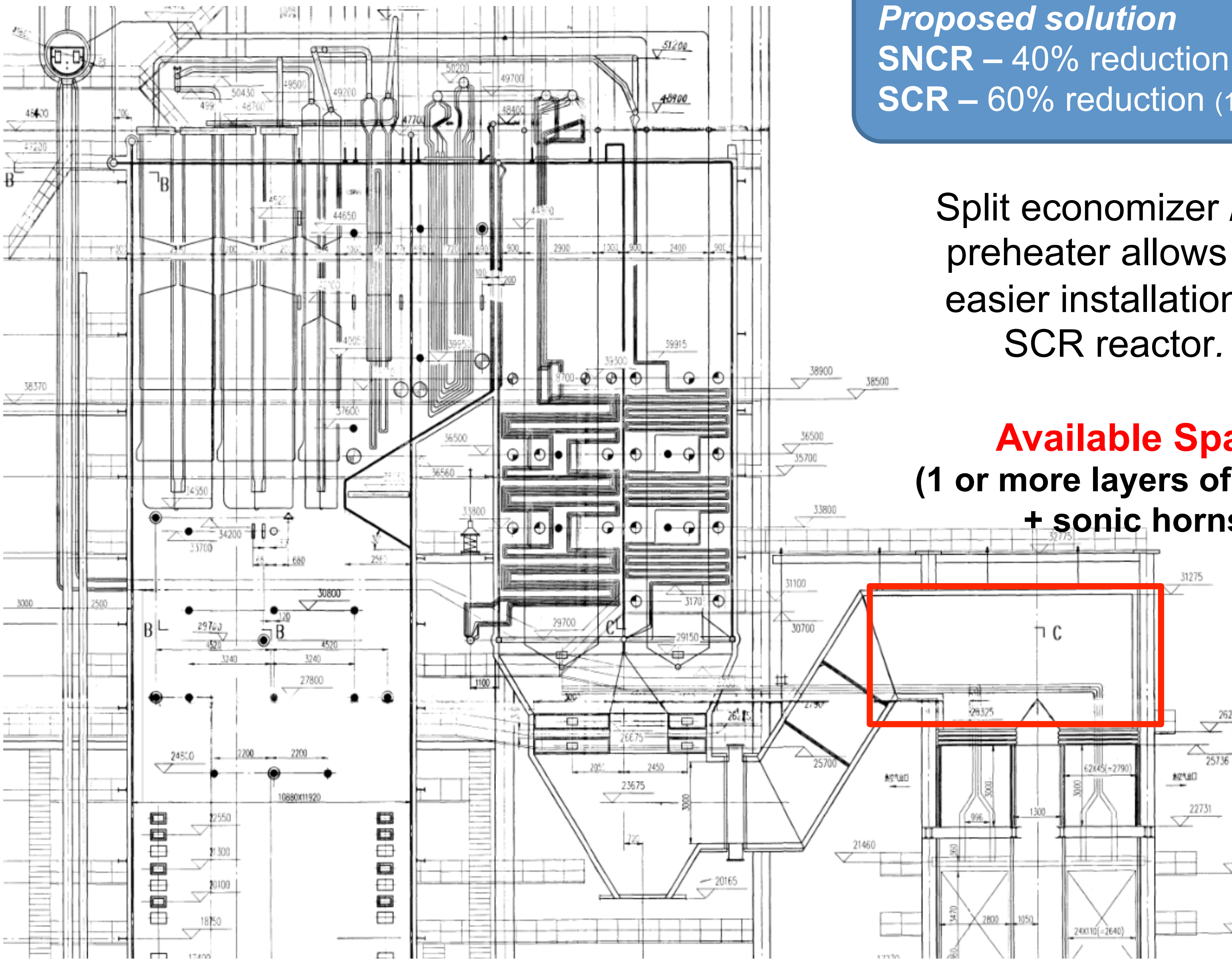


Proposed solution

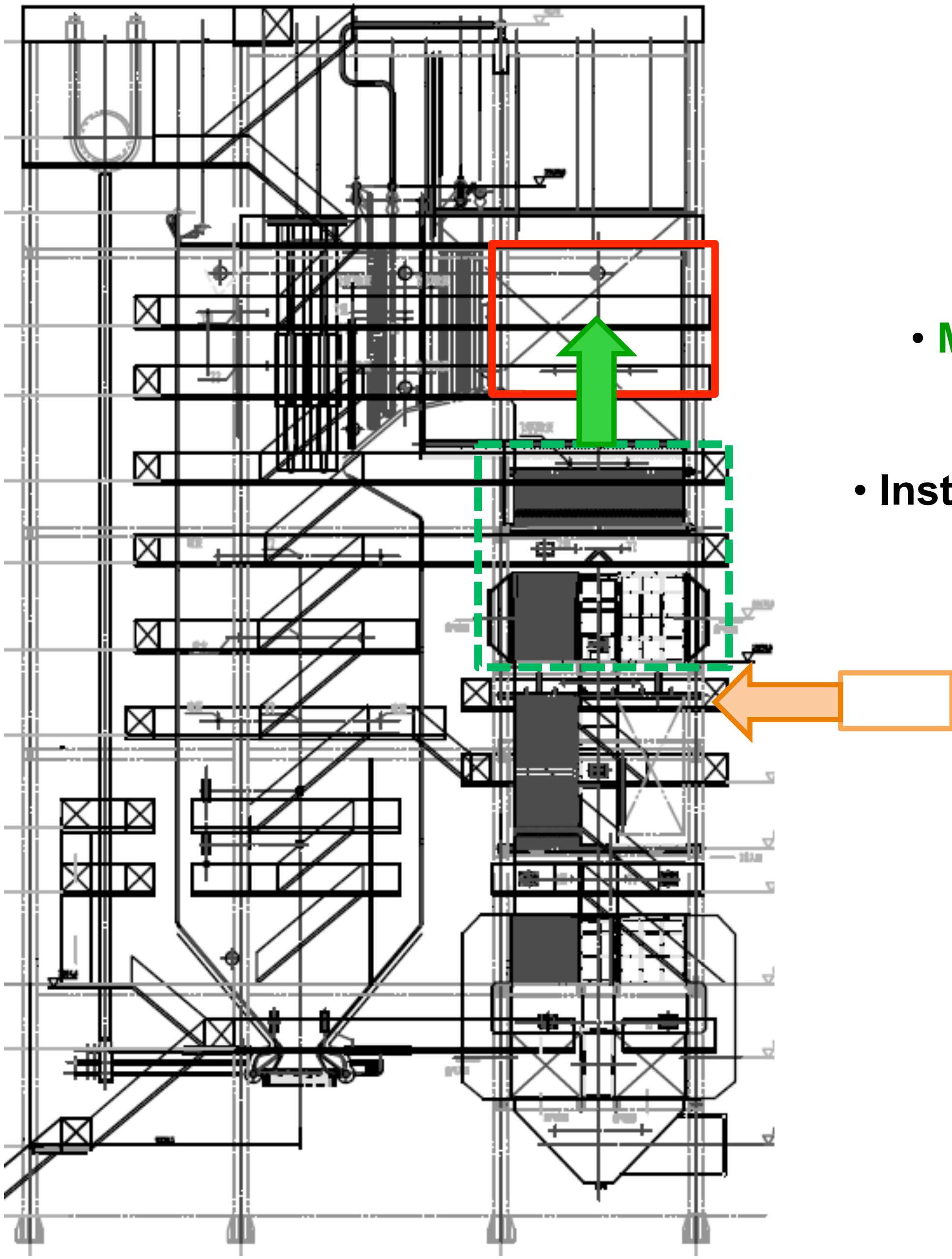
SNCR – 40% reduction (250 mg/Nm³)

SCR – 60% reduction (100 mg/Nm³)

Split economizer / air preheater allows for easier installation of SCR reactor.

Available Space

(1 or more layers of catalyst + sonic horns)



Proposed solution

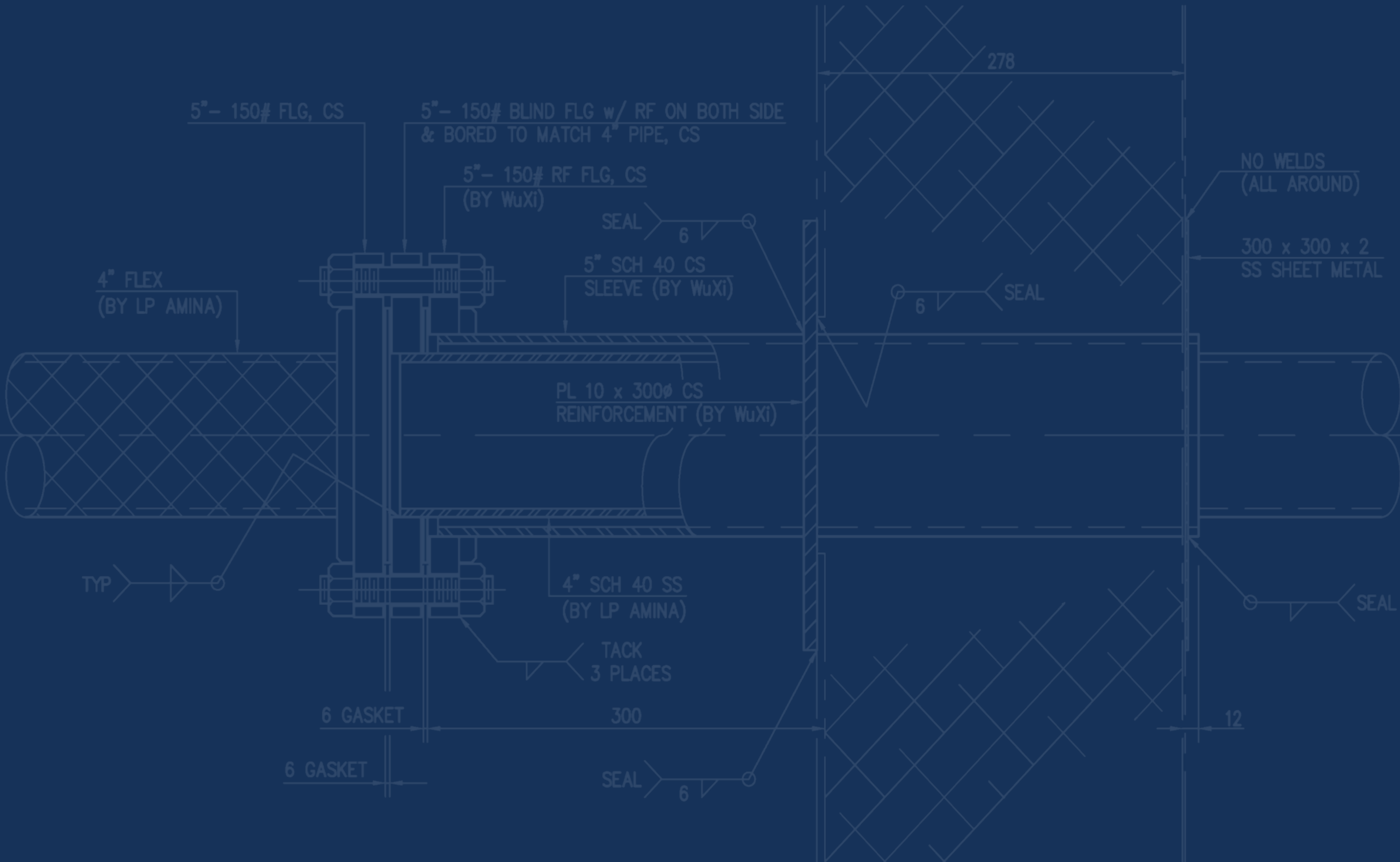
SNCR – 40% reduction (166 mg/Nm³)

SCR – 40% reduction (100 mg/Nm³)

Available Space TOO HOT

- **Move economizer, APH upwards.**
- **Create new space below in correct temperature zone.**
- **Install 1 layer of catalyst + sonic horns**

Harder installation than other examples because of lack of space in correct temperature zone.



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Hybrid SNCR/In-Duct SCR System

Dale Pfaff

FUEL TECH, INC.

Batavia, IL

Rich Abrams

BABCOCK POWER ENVIRONMENTAL

Worcester, MA

Environmental Controls Conference – Pittsburgh, PA

May 16 – 18, 2006

Agenda

- Hybrid Defined
- SNCR
  - Traditional
  - Re-Designed
- Compact SCR Design
  - Tools
- Hybrid Goals
- Real Life Examples
- Costs

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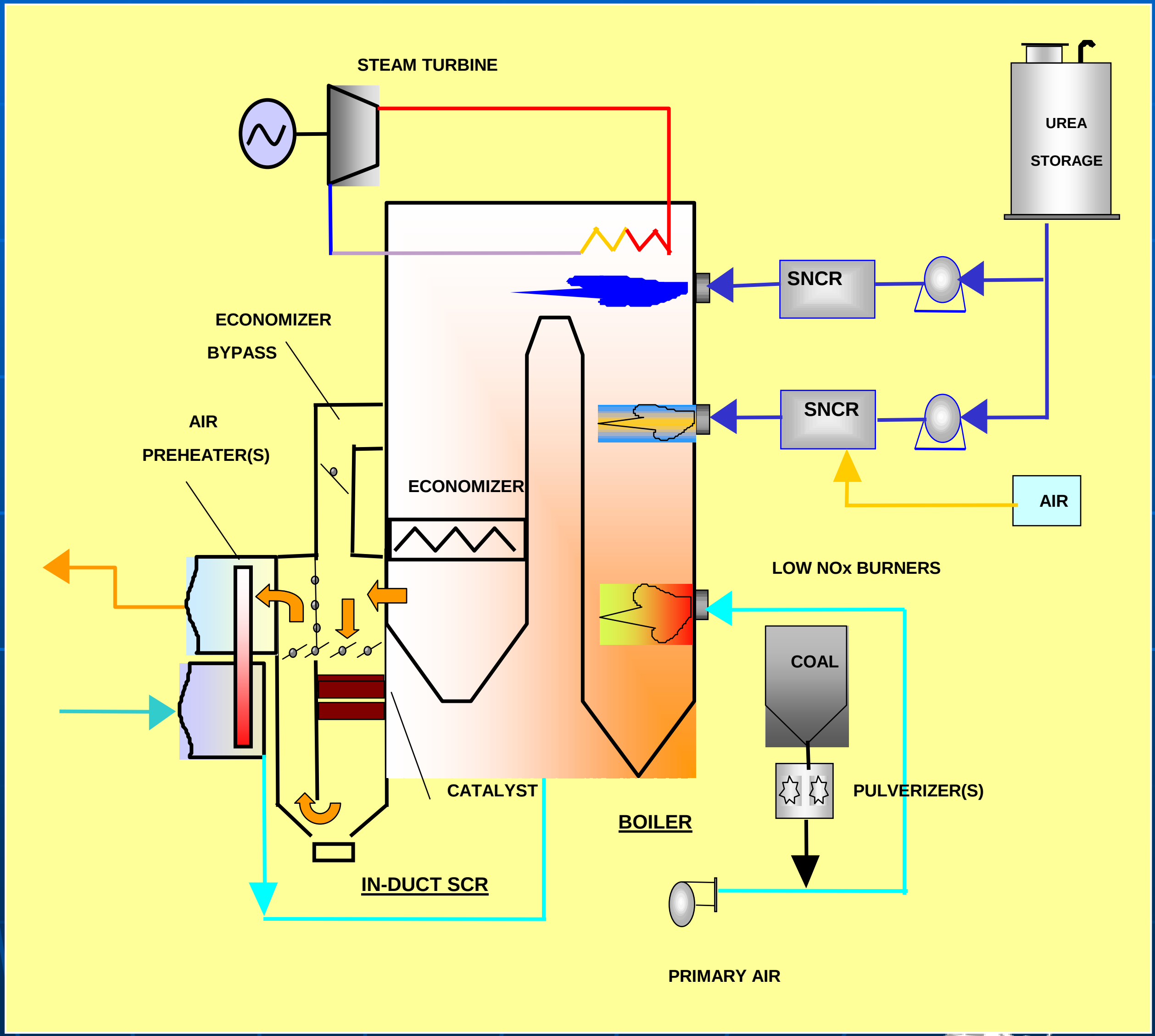
FUEL TECH® Technology for a renewed environment™

Hybrid NO_x Control System "Cascade®"

- **Redesigned** SNCR System with SCR (using urea)
- Higher NO_x Reduction and Utilization than SNCR
- NH_3 slip consumed in SCR
- Low SO_2 to SO_3 Conversion Rates
- 50 - 75% overall NO_x reduction
- Low capital costs



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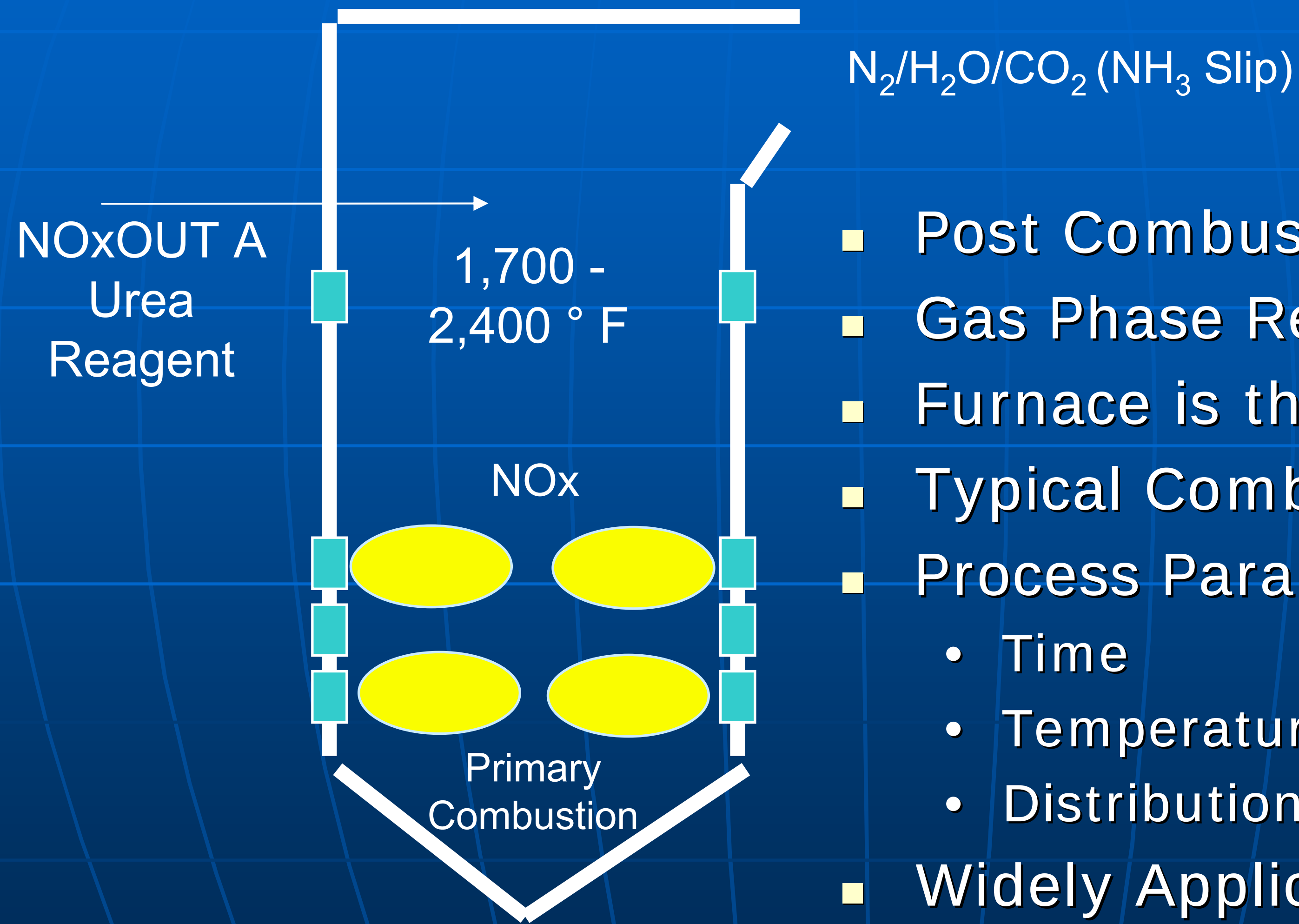
Traditional Urea Based Selective Non-Catalytic Reduction (SNCR) of NOx



- Post Combustion
- Gas Phase Reaction
- Furnace is the Reactor
- Typical Combustion Products
- Process Parameters
  - Time
  - Temperature and Species
  - Distribution
- Widely Applicable

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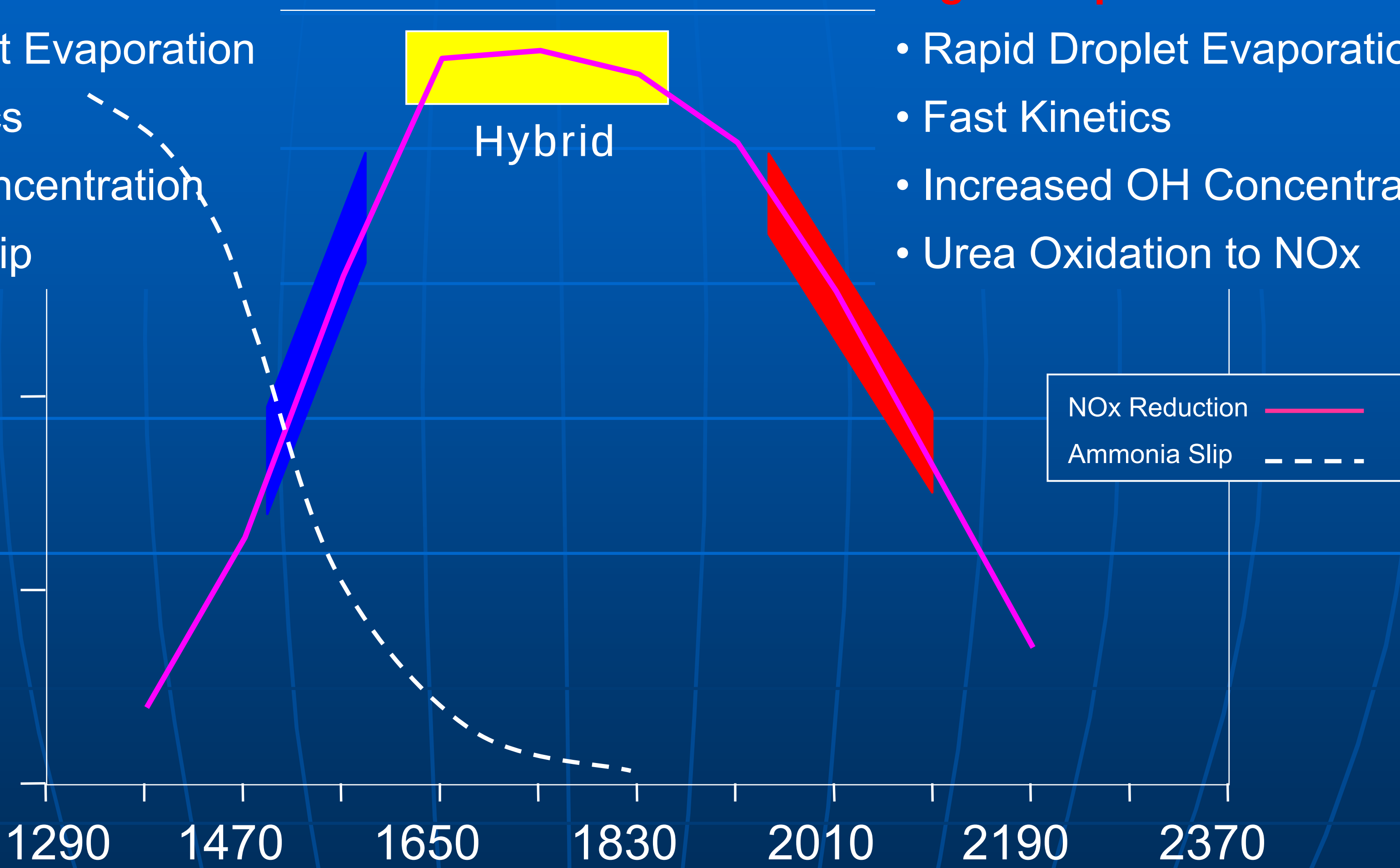
“Right Side of the Slope” Injection

Low Temperatures

- Slow Droplet Evaporation
- Slow Kinetics
- Low OH Concentration
- Ammonia Slip

High Temperatures

- Rapid Droplet Evaporation
- Fast Kinetics
- Increased OH Concentration
- Urea Oxidation to NOx



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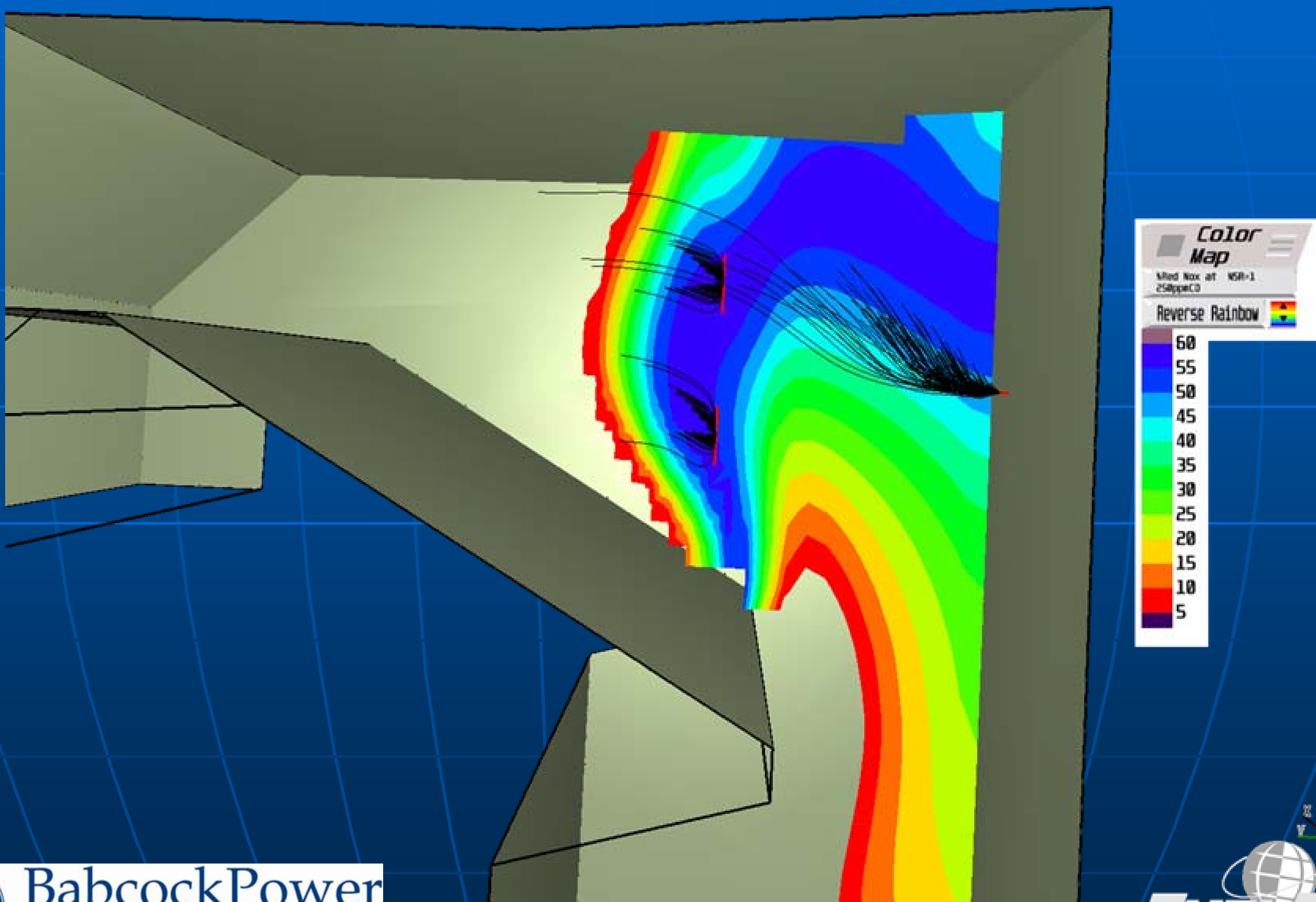
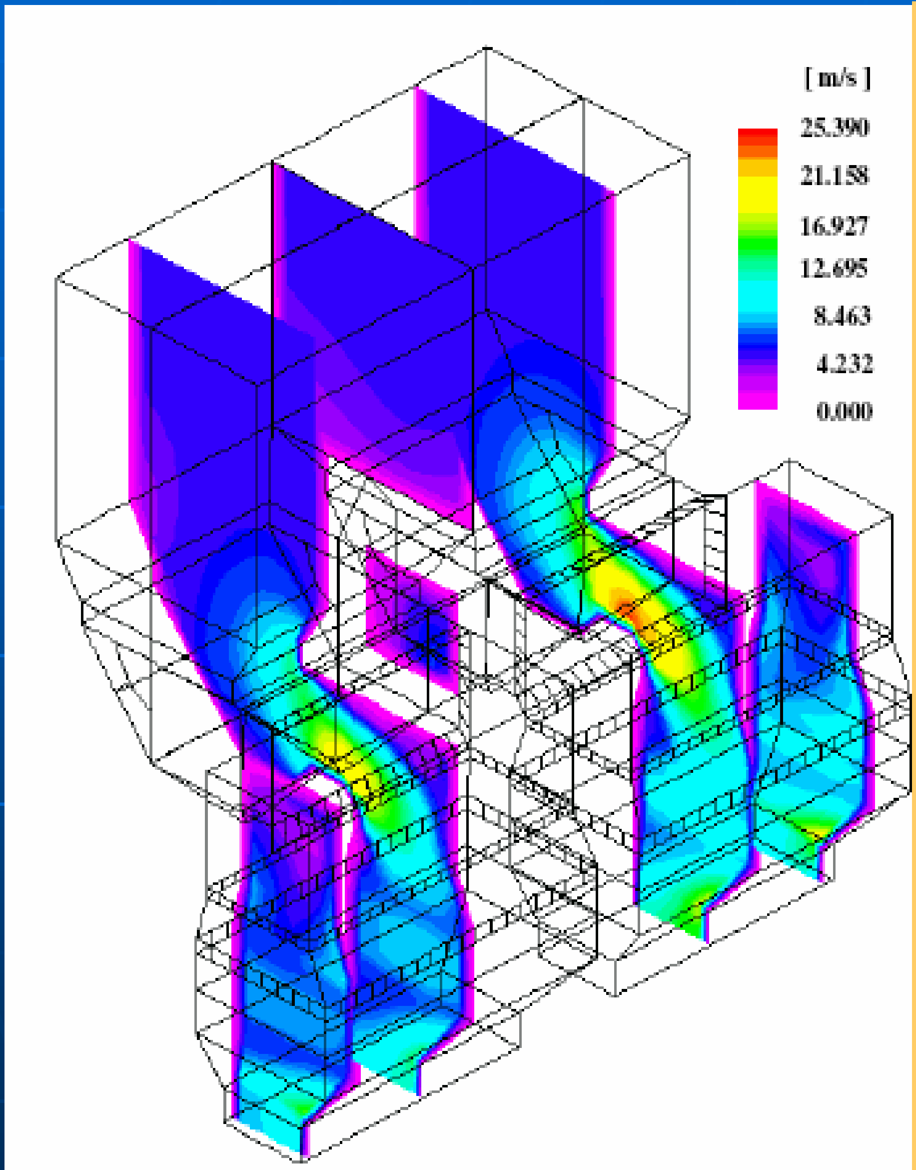
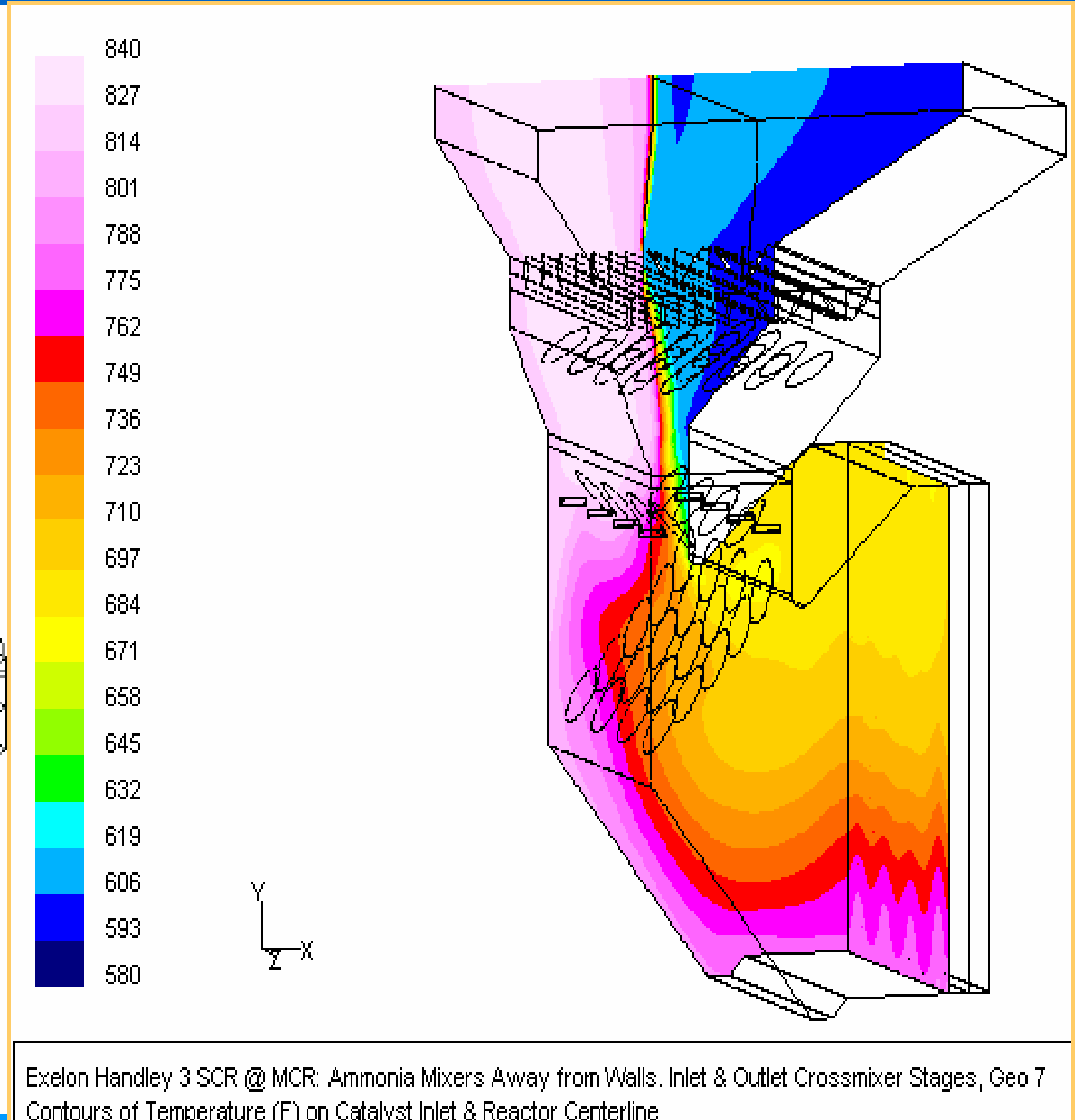
Hybrid SNCR Injection



Hybrid In-Duct





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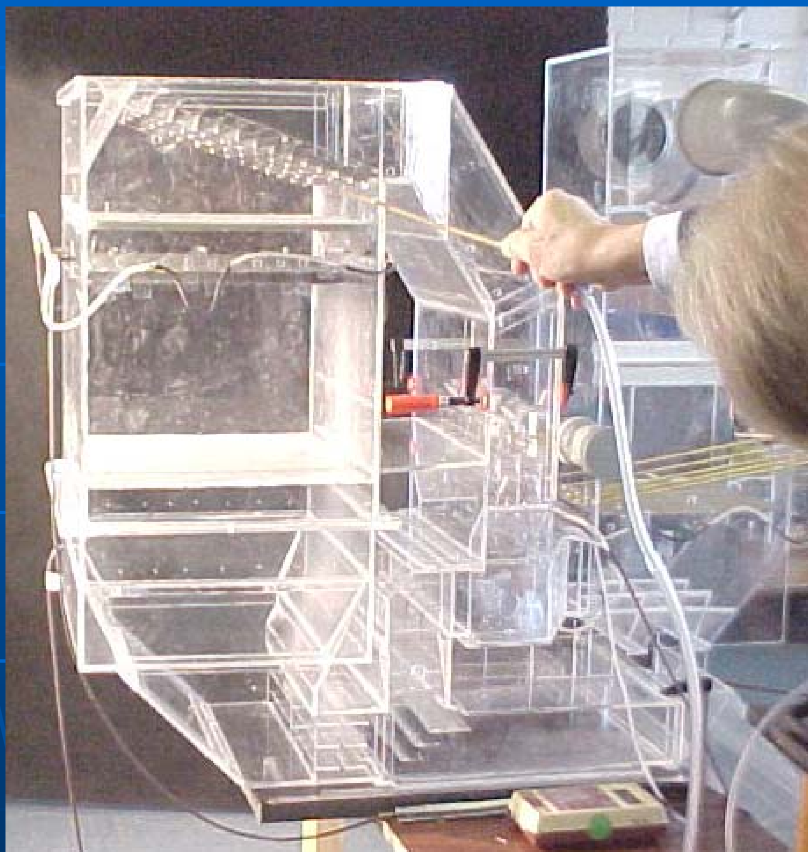
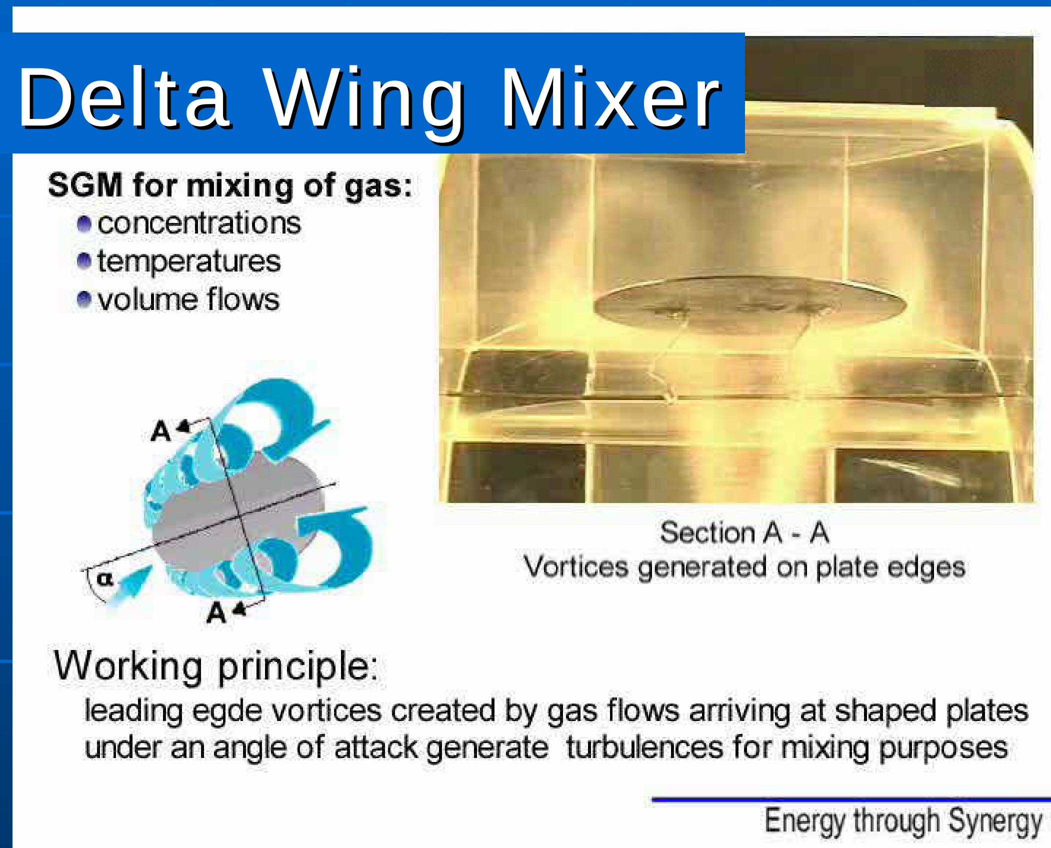
Cold Flow Models and Flue Gas Mixing

- **1:40 scale flow model**





BPI makes extensive use of flow modeling to guide designs and to ensure proper distribution

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Typical Hybrid Process Goals

- Multiple Levels of SNCR Injection for Load Following Capabilities
- 50 - 75% Overall NOx Reduction, 2 - 5 ppm NH_3 Slip
- One Catalyst Layer at 1.3 m Depth
- SCR Inlet Temp = 650 °F Norm / 800 °F Max
- No Ammonia Injection Grid
- Efficient Mixing to Achieve Uniform Distribution
- SO_2 to SO_3 Conversion < 0.5 %
- Fits within the Physical Space Limitations

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Commercial Compact SCR and Hybrid (SNCR/SCR) Examples

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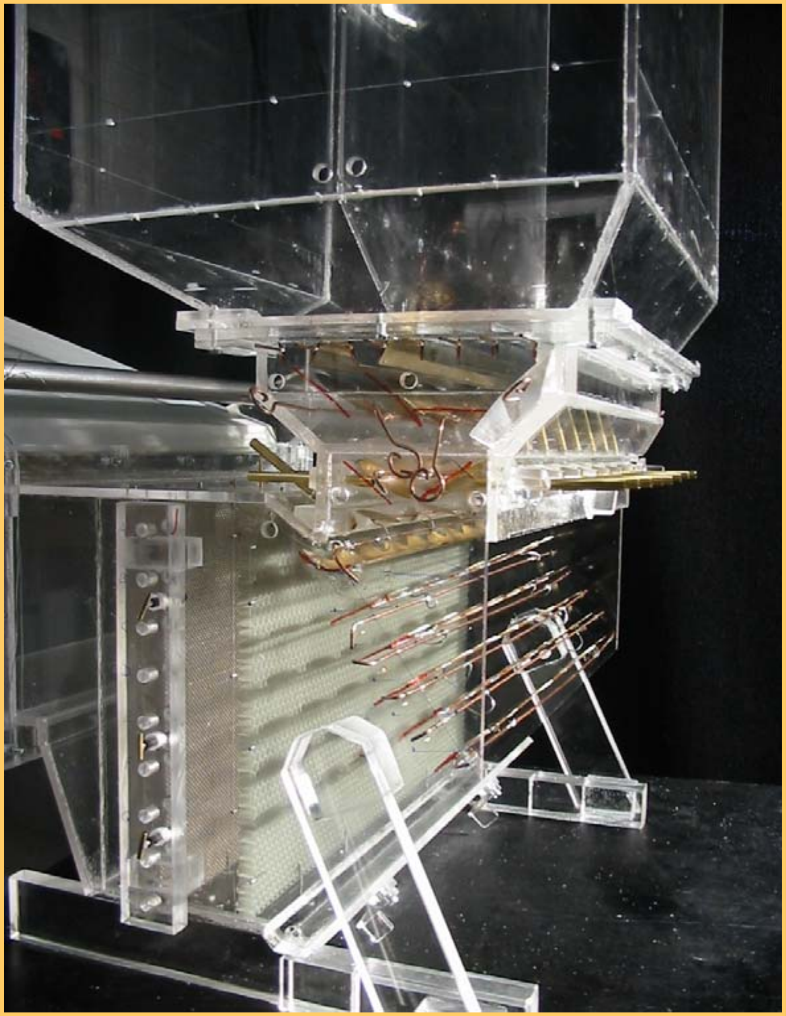
Example 1: Compact In-Duct SCR
Exelon Handley Unit 3

- Turbo Boiler – Gas Fired
- 94% NOx Removal SCR
- In-duct Reactor
- Delta Wing Mixing System
- Honeycomb Catalyst



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BPI - Handley Test Results

- Full load and low load NOx outlet concentrations achieved at 0.02 and 0.01 lbs/Mmbtu respectively
- NOx removal efficiencies of >94%
- Stack ammonia slip <3 ppm measured
- SCR system pressure loss as predicted
- NH3/NOx ratios < 6% RMS, per design
- Optimization of unit in six operating days

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Example 2: Fuel Tech
Seward Station - 147 MWg, Coal

- T-fired CE furnace: 1990 BL of 0.78 lb/MMBTU
- Furnace and convective pass injection

Design Case:

42% reduction, 0.45 #/MMBtu, <5 ppm NH_3 slip

Operational Case:

35% reduction, 0.50 #/MMBtu, <2 ppm NH_3 slip

Less than 10 % in convective pass

High Ammonia Slip Case

54% reduction, 0.36 #/MMBtu, ≈10 ppm NH_3 slip

Short-term testing

- Increased chemical in convective pass

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SCR Expanded-duct Reactor Design

- Required NH_3 Reduction from 20 ppm to 2 ppm
- Rapid Flue Gas Mixing
- Minimum SO_3 production (Ammonium Salts)
- Minimum pressure drop
- Withstand coal fired gas stream

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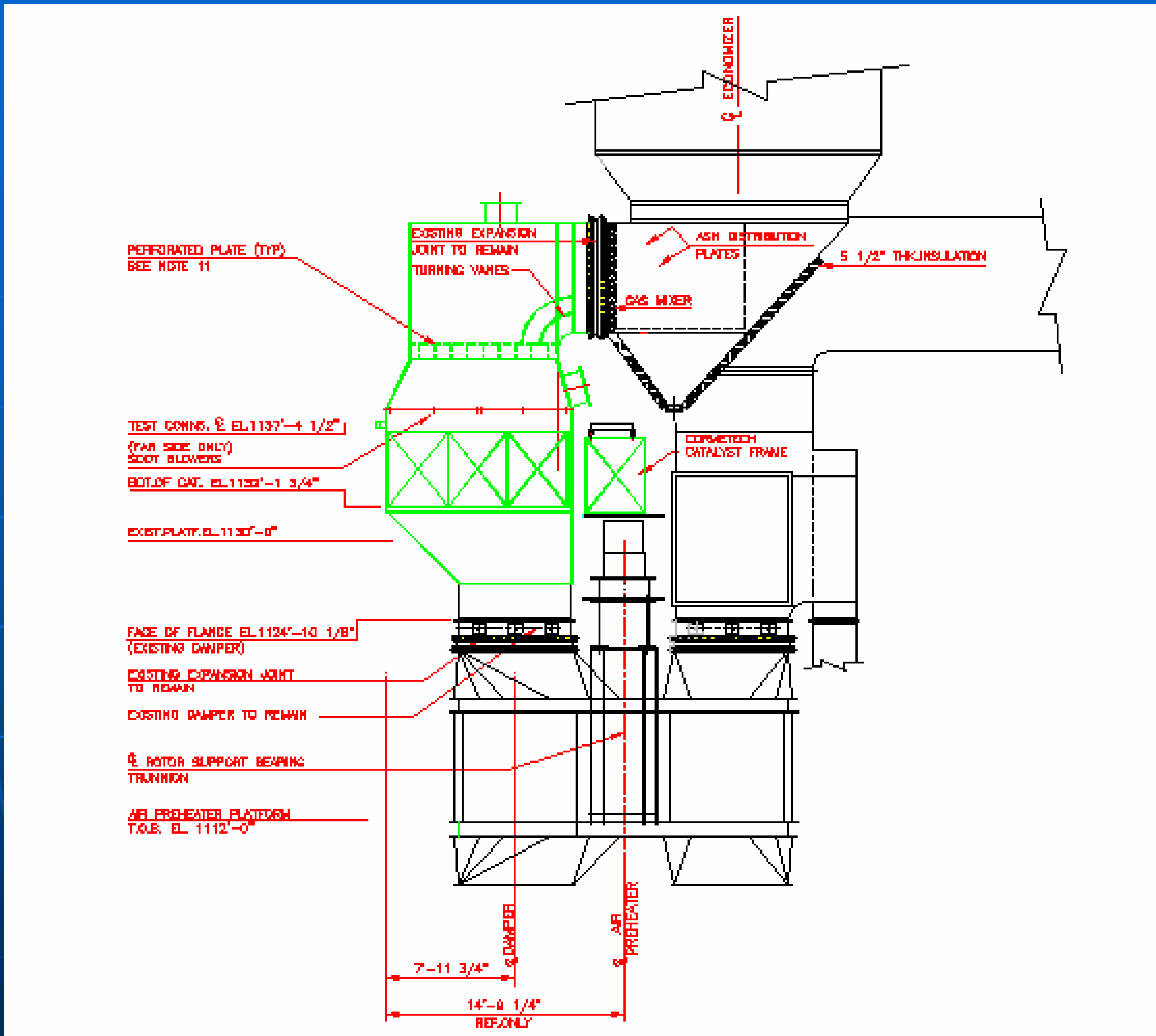

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Hybrid SNCR/SCR Performance

- Maximum Reduction Achieved (>50%)
  - System Tuned to 2, 10, or 20 ppm slip
  - Low-Load Operation at 2 ppm Slip.
- Increased Chemical Utilization
- Less than 2 ppm ammonia slip at SCR Outlet
- Hybrid SNCR/SCR Operated for more than 5 years

Example 3; High Load (320MWe) Hybrid Results

Fuel	NOx Control System	NSR	SNCR Reduction	SNCR Utilization	SCR Reduction	Total Reduction	Overall Utilization
Coal	Standard SNCR	1.19	37.0%	31.1%	-	37.0%	31.1%
Coal	Hybrid	0.79	41.1%	59.2%	16.3%	50.7%	64.2%
Coal	Hybrid	1.15	36.9%	45.7%	54.2%	71.1%	61.8%
Gas	Hybrid	1.44	36.1%	38.6%	78.9%	86.5%	60.1%
Gas	Hybrid	1.56	39.0%	37.1%	83.6%	90.0%	57.7%

- Ammonia Slip at 10 ppm or less

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Example 4; AES Greenidge Application Hybrid System

- 115 MW Coal Fired Unit, 2.9% S Bituminous coal
- Two levels of SNCR
- In-duct reactor; single layer of catalyst
- Short distance between economizer and reactor
- SNCR provides ~ 40% reduction
- SCR provides balance
- Overall system provides ~ 66% reduction

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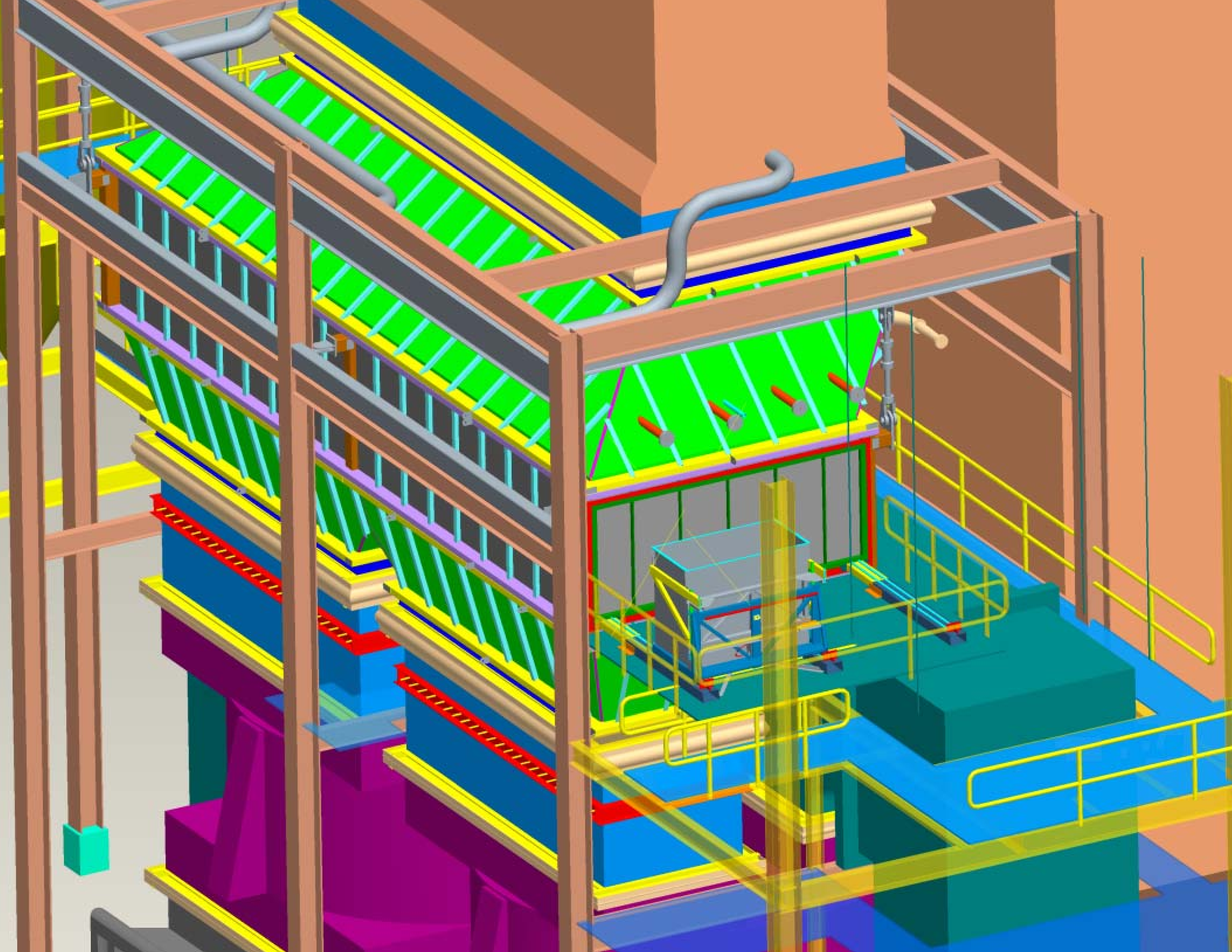

All-In Capital Cost vs. NOx Reduction

SCR	$70 - +$200?/KW	80 - 90%
SNCR	$10 - $30/KW	20 - 35%
Hybrid	$35 - $80/KW	50 - 75%

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Conclusions

- Hybrid combines redesigned SNCR with SCR
- Control Flexibility: Operating vs. Capital Costs
- Hybrid can control slip and improve utilization
- 50% and 75% NOx Reduction with significantly reduced SCR retrofit capital
- Each Unit Must Be Evaluated to Determine Feasibility for placement of an IN-DUCT or COMPACT SCR.
- 2 Utility and 3 Industrial Hybrid Applications

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ATTACHMENT C

<u>Questions Submitted via Email to Randy Mosier (MDE) from Leah Kelly (EIP) on April 4, 2017</u>

In response to Public Information Act ("PIA") request #2017-00093 relating to the Wheelabrator BRESCO incinerator in Baltimore, we received a NO_x Control System Optimization Final Report compiled by Quinapoxet Solutions for tests run in February and March of 2016 at Wheelabrator Baltimore (hereinafter "Final Report"). We have a few questions relating to this report and hope that MDE is willing to consider these.

We still intend to submit a longer set of comments later this month as stakeholders in the NOx RACT for Large MWCs process, which will address additional issues, but we wanted to get these inquiries in as soon as possible.

1. **What analyses did Wheelabrator conduct to measure or model the furnace gas flows?**

In the Final Report, Quinapoxet Solutions states that "it was confirmed that furnace gas flows favored the rear wall at the urea injection level." However, it was unclear within the report what tests were conducted to confirm this assertion, as the report refers to "Typical Boiler Furnace Flow" in Figure 6 to support its assertions. Is MDE aware of whether a computational fluid dynamics model or similar flow testing has been done on the Wheelabrator Boiler Furnaces?

2. **Has Wheelabrator conducted temperature measurements at varying heights within the furnaces to verify that the 4th floor is the optimal location for the SNCR Injector?**

Wheelabrator's presentation at the 1/17/17 NOx stakeholder meeting indicated that adequate residence time may be a concern for the single-pass boiler, and additional vertical testing could inform additional or modified urea injection at varying heights or angles within the furnace.

3. **Is the GasTemp pyrometer (line of sight average) appropriate for temperature profiling?**

When determining placement of injection locations, more detailed spatial data may be required. Using an instrument that gives you the average along a line is valuable in some contexts, much more granular data should be obtained to identify exact placement of urea injection.

4. **Could there be the opportunity to further optimize baseline combustion controls?**

The Final Report attributes the higher baseline concentration within Boiler 2 to be due to the higher operating temperature required in a "fouled" boiler. However, due to the relatively low operating temperatures of the boilers, it is unlikely that thermal NOx would cause the 20 ppm difference between the two baselines. We are curious whether additional factors, such as fuel composition or boiler operation, are contributing to these observed differences, and whether better standardization or optimization could reduce baseline emissions before SNCR treatment.

5. **If possible, can MDE provide the urea flow for *each* injector during testing in addition to total flow?**

6. **Have the injection locations identified within the optimization study or the urea injection rates been implemented, and do they continue to be utilized currently?**

7. **Was the optimization study protocol approved by MDE?**