A Review of the Record Concerning the Technical Feasibility of Selective Catalytic Reduction on North Dakota Lignite Electric Generating Units

Prepared by

Joe Kordzi and Ranajit Sahu, Consultants

On behalf of

National Parks Conservation Association and Sierra Club

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1 Introduction

This report examines the technical feasibility of selective catalytic reduction (SCR) technology at North Dakota lignite-burning electric generating units (EGUs). Lignite-fired coal plants in North Dakota are among the highest nitrogen oxide (NOx) emitters in the US coal-plant fleet today. Based on 2019 data, four North Dakota lignite units rank among the top 25 highest NOx emitters in the US, (which also had among the highest NOx rates at approximately 0.45 lb/MMBtu) at 5,359 tons; Milton R. Young Station Unit 2 (MRYS 2) at 5,141 tons; Coal Creek Unit 1 at 4,004 tons; and Leland Olds Unit 2 (LOS 2) at 3,982 tons.

During the first round of regional haze SIPs in September of 2011, almost a decade ago, the technical feasibility of SCR at North Dakota lignite EGUs was a highly contentious issue. Initially, EPA proposed to correct deficiencies in North Dakota's SIP with a Federal Implementation Plan (FIP), concluding best available retrofit technology (BART) for NOx at Leland Olds Unit 2, and Milton R. Young Units 1 and 2 should correspond to limits resulting from the installation of SCR. The owner of those facilities, Minnkota, steadfastly maintained that, based on the unique aspects of Milton R. Young's cyclone-fired boilers and due to the high alkali and/or alkaline earth metals, primarily sodium, in the lignite Minnkota burns, SCR in any configuration was infeasible. North Dakota initially agreed that SCR in any configuration was technically infeasible, then concluded that certain SCR configurations were technically feasible, then ultimately concluded all configurations were technically infeasible. In its final approval of North Dakota' SIP, the Environmental Protection Agency (EPA) reversed course and concluded that the state's determination regarding the feasibility of tail end SCR for North Dakota's lignite burning EGUs was not unreasonable.[1] Although EPA extended that determination to Coyote, the agency also noted that it may have reached different conclusions had EPA been conducting the analysis or if additional information had been available. EPA specifically noted, however, that it expected the state to revisit both the range of technically feasible controls and cost-effectiveness of those controls in the second round of regional haze SIPs.[2]

This report is intended to assist the North Dakota Department of Environmental Quality (DEQ) and EPA in revisiting the issue of the technical feasibility of SCR at lignite-fired EGUs. The report is organized as follows: first, we re-evaluate the first round rulemaking record regarding the implementation and feasibility of SCR at lignite-burning power plants; second, we review new or recent technical information developed over the last decade. We conclude that SCR is technically feasible at North Dakota lignite-fired power plants. Further, based on a separate analysis, it is our opinion that SCR should be cost effective at several of North Dakota's power plants.[3]

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[1] 77 FR 20899/2, 20936/2 (April 6, 2012). EPA's reversal was due, in part, to a district court decision in a separate Clean Air Act enforcement action, in which the court deferred to North Dakota Department of Environmental Quality's assessment that, based on the "unique boiler and lignite characteristics" at Milton R. Young, SCR was technically infeasible. Order Denying Mot. for Stay and Mot. for Dispute Resolution, *United States v. Minnkota Power Cooperative, Inc*., No. 1:06-cv-00034-DLH-CSM (D. N.D.), ECF Doc. 35.

[2] 77 FR 20937/2 (April 6, 2012).

[3] For example, see the separate report on the feasibility of Tail-end SCR at Coyote Station.

2 Framework for this Report.

We believe that the intended focus of most of the literature reviewed in this report can be distilled down to two fundamental questions, identified by Minnkota's consultants in 2009: [4]

- The first fundamental question is "how to estimate the amount (mass rate) of sodium and in what size range could be emitted from the boilers at MRYS, for the purposes of" a best available control technology (BACT) analysis.

- The second fundamental question is "for the purposes of a BACT analysis, what rate of catalyst deactivation is likely to occur as a result of exposure to the expected particle or aerosol size range and concentration of sodium emitted from a boiler over a given period of time?"

Although we believe these are important questions, we do not believe they should form the basis of a determination of North Dakota lignite SCR technical feasibility. Inherent in these questions is the acknowledgement that an SCR system is technologically feasible for North Dakota lignite power plants, with the only issue being how long the catalyst will continue to function before it becomes sufficiently deactivated and must be regenerated or replaced. Few actual implementation problems have been raised regarding other aspects of the SCR system, and as we describe in this report, we believe they have all been satisfactorily addressed. These aside, we could not find any claim in the record from North Dakota, Minnkota, or Minnkota's consultants that any SCR configuration would simply not remove NOx from the exhaust at Milton R. Young. All of the feasibility claims concern catalyst life. Catalyst life does not distinguish a North Dakota lignite SCR system from any other SCR system, as all SCR systems eventually require catalyst regeneration or replacement. Rather, as with all SCR systems, catalyst life is a cost issue—not a technical feasibility issue. [5] Of course, this does not remove catalyst life as a consideration, as it must still be known in order to design and cost a SCR system. Instead, it shifts the catalyst life considerations from a threshold feasibility issue to a cost issue. If a shorter catalyst life is indicated for a particular configuration, it is properly considered in the cost-effectiveness calculation at which point it can be compared with other NOx controls. Thus, we conclude that North Dakota's use of a 10,000 hour catalyst life as a *technical feasibility* threshold is misplaced.

We also believe that an unwarranted amount of emphasis has been placed on catalyst vendor guarantees, which should not be considered as a primary determinant of technical feasibility. As the NSR Manual makes clear: "lack of a vendor guarantee by itself does not present sufficient justification that a control option or an emissions limit is technically infeasible. Generally, decisions about technical feasibility will be based on chemical, and engineering analyses ... in

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[4] Supplemental Information for Consideration by NDDH Regarding NOx BACT for Milton R. Young Units 1 and 2: Technical Feasibility issues for TESCR or LDSCR Retrofit. Prepared for Minnkota Power Cooperative, Inc., and Square Butte Electric Cooperative, February 20, 2009. Prepared by Burns & McDonnell Engineering Company, Inc. Kansas City, Missouri and Steve Benson, PhD Department of Chemical Engineering, University of North Dakota. Project No. 31777. See page 33.

[5] After the initial catalyst fill, catalyst life is considered an operating and maintenance cost in calculating cost-effectiveness.

conjunction with information about vendor guarantees."[6] This same language is present in EPA's BART Rule.[7] Thus, vendor guarantees are in fact a secondary consideration. This means that even if catalyst vendors were completely unwilling to provide guarantees, the consideration of technical feasibility could still move forward. We saw no indication that catalyst vendors were unwilling to sell catalyst, and some were in fact willing to offer guarantees, even after Minnkota and its consultants' subsequent questioning. Therefore, a reasonable strategy would be to assume a conservative catalyst life in the cost-effectiveness analysis. To that end, we review the record in order to clarify the issue of catalyst life. During the first round of regional haze planning, Minnkota's analysis focused on characterizing the exhaust gas stream at Milton R. Young and attempting to demonstrate that certain alkali and/or alkaline earth metals, which are higher in North Dakota lignite than many other U.S. coals (but not uncommon in global fuels), cause catalyst deactivation. Even after years of study, however, including multiple data gathering efforts, Minnkota never actually attempted to directly calculate the mass flow rate of these constituents that SCR catalyst would experience at various SCR configurations, despite their own acknowledgement that this was a fundamental input to determining catalyst life. Instead, Minnkota focused on citing to studies that alkali and/or alkaline earth metals caused catalyst deactivation, and when it did gather data, it focused on particle size fractionation.

Nevertheless, we take up that challenge. In so doing, we simplify Minnkota's fundamental questions to:

> (1) What is the mass loading of alkali and/or alkaline earth metals a low dust SCR (LDSCR) and a tail end SCR (TESCR) would experience at North Dakota lignite fueled EGU, and
>
> (2) What effect would these mass loadings have on catalyst life?

Throughout our review of the record, we continually go back to these two fundamental questions in an attempt to identify which information can be used to address them and which information is in fact a distraction.

In conducting our assessment we evaluated numerous documents. The key documents are provided in Table 1 below.

Table 1 – Key Documents and Dates

Date	**Short Name**	**Summary**
11/2004	November 2004 EERC Slipstream Report	Slipstream testing was conducted at three EGUs to determine the propensity of the PRB and North Dakota lignite to plug SCR catalysts.
06/2008	June 2008 North Dakota Prelim BACT Determination	North Dakota Concludes that SCR is not technically feasible for Milton R. Young in any

[6] Draft, October 1990, New Source Review Workshop Manual, Prevention of Significant Deterioration, and Nonattainment Area Permitting, page B20.
[7] 70 FR 39165 (July 6, 2005).

		configuration. EPA disagrees and replies with its own comments (including July 2008 Hartenstein Report).
07/2008	July 2008 Hartenstein Report[8]	Criticizes the 2004 EERC Slipstream Report and North Dakota Preliminary June 2008 BACT Determination for Milton R. Young.
05/2009	May 2009 North Dakota SCR BACT Feasibility Report[9]	BACT SCR technical feasibility analysis – App. B.6 of the 2010 North Dakota RH SIP. Concludes HDSCR is not technically feasible but LDSCR and TESCR are technically feasible.
11/2009	July 2009 North Dakota SCR BART Report[10]	BART SCR technical feasibility analysis – App. B.5 of the 2010 North Dakota RH SIP. Concludes HDSCR is not technically feasible but LDSCR and TESCR are technically feasible.
07/2009	July 2009 Microbeam Report	Samples the exhaust gas stream at various points in the pollution control train at Milton R. Young.
04/2010	April 2010 North Dakota Prelim BACT Determination	North Dakota determines HDSCR is infeasible and has "significant concerns" about the technical feasibility of LDSCR and TESCR. North Dakota determines BACT is SNCR.
05/2010	EPA Comments April 2010 Prelim BACT Determination	Focuses on cost and BACT procedures and regulations and does not address technical feasibility. Not reviewed in this report.
11/2010	November 2010 North Dakota Milton R. Young BACT determination	Includes key documents in North Dakota's BACT determination.
09/2011	September 2011 North Dakota SIP-FIP proposal	EPA concludes SCR is feasible for North Dakota lignite EGUs.
12/2011	December 2011 Milton R. Young BACT Litigation	The Court agrees with North Dakota that SCR in any configuration at Milton R. Young is technically infeasible.
04/2012	April 2012 North Dakota SIP-FIP final	EPA reverses its proposed position that SCR was feasible for North Dakota lignite EGUs.
03/2013	March 2013 North Dakota SIP-FIP Reconsideration proposal	EPA reconsiders its April 2012 North Dakota SIP-FIP final.

[8] There is also a subsequent October 2008 Hartenstein report that is attached as part of Appendix C to the April 2010 North Dakota Prelim BACT Determination noted later in this table.

[9] This report is undated but assumed to be written during May 2009, as May 1, 2009 is the latest date used in the report and it does not mention the July 2009 Microbeam report. Its content is very similar to the subsequent July 2009 North Dakota SCR BART report.

[10] Note that in both (1) a Minnkota email from Ronald Bryant to Noel Rosha of CERAM, dated 8/26/2009 (attached to end of the Microbeam report) and (2) in Haldor Topsoe's 10/12/2009 Catalyst specification (attached as Appendix D to April 2010 North Dakota Prelim BACT Determination), reference is made to a 8/20/2009 Microbeam report. We have been unable to locate a version of this report with this date if such a report exists.

02/2015	February 2015 North Dakota SIP-FIP Reconsideration Final	EPA reaffirms its April 2012 final determination that SCR is not feasible for North Dakota ignite EGUs.

3 Review of Key Documents

We begin with a re-evaluation of the key documents used in the first round of SIPs that frame the technical debate of the feasibility of SCR on North Dakota lignite EGUs, as EPA instructed in its final approval of that SIP. Although the district court in the Minnkota Clean Air Act litigation deferred to North Dakota DEQ's determination of the feasibility of SCR as BACT for lignite facilities, EPA noted that "while (as noted elsewhere in this notice) we do not view the Minnkota Power decision as binding or determinative, we do view it as relevant to our consideration of this matter."[11] Indeed, EPA explicitly directed North Dakota DEQ to revisit this issue because:[12]

> technological advances elsewhere may yet provide compelling information to drive further testing on North Dakota lignite or negate the need for such testing. As noted above, we expect that North Dakota will reassess the technical feasibility of SCR controls at these plants as part of a future reasonable progress analysis.

This analysis is intended to assist North Dakota DEQ and EPA in re-evaluating the technical feasibility of SCR at lignite-fired North Dakota EGUs.

3.1 November 2004 EERC Slipstream Report

In November 2004, the Energy & Environmental Research Center University of North Dakota (EERC) issued its Slipstream Report, which was intended to provide information on the suitability of SCR on North Dakota lignite-fired cyclone boilers.[13] Two bench-scale SCR slipstream reactors were installed at the Columbia Station (pulverized coal-fired), the Baldwin Station (cyclone-fired), and the Coyote Station (cyclone-fired). The Coyote Station burned North Dakota lignite, while the other two stations burned Powder River Basin (PRB) coal. Although the testing provided some data concerning catalyst plugging, including compositional analysis, it did not measure catalyst deactivation. A number of reviewers, including Hans Hartenstein, Phyllis Fox, and North Dakota itself have concluded that the testing ultimately did not provide much useful data concerning the technical feasibility of any configuration of SCR for any boiler or fuel type. Much of this is due to concerns over the selection of catalyst type and pitch and whether the instrumentation adequately simulated a full-scale SCR operation.

EERC's main conclusions applicable to this report were:

[11] See 80 FR 8552 (February 18, 2015).
[12] See 80 FR 8553 (February 18, 2015).
[13] Evaluation of Potential SCR Catalyst Blinding During Coal Combustion and Add-On: Impact Of SCR Catalyst on Mercury Oxidation in Lignite-Fired Combustion Systems, Final Report, Energy & Environmental Research Center University of North Dakota, November 2004.

- The catalyst in all three slipstream reactor tests showed much ash accumulation but the North Dakota lignite-fired Coyote test showed the most accumulation.

- The deposits on the surfaces and within the pores of the catalyst consisted mainly of sulfated alkali and alkaline-earth metal-rich constituents. X-ray diffraction (XRD) analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases.

- The authors recommend that careful evaluation should be made for SCR installations that burn using subbituminous and lignite coals. Improvements are needed to ensure technical feasibility, especially with lignite-fired units. Installations involving lignite fuels will need advanced cleaning techniques to handle the high sodium and high dust loads associated with burning most lignite fuels.

We make the following observations regarding this report:

- On page 16 of the report, EERC states that the slipstream sampling port was located upstream of the air heater. This indicates that the testing equipment was configured in an attempt to simulate a high dust SCR (HDSCR) environment. Thus, none of the report's conclusions apply to low dust or tail-end SCR installations.

- The degree of catalyst deactivation, the keystone consideration of SCR technical feasibility, was only reported for the Baldwin unit, which did not burn North Dakota lignite. Although catalyst plugging was considered, it is suspect for other reasons discussed below. Thus, the overall utility of this report in the consideration of North Dakota lignite SCR technical feasibility is questionable.

- The slipstream reactor test chambers were only 7.5" square. No evidence was presented to ensure these reactors didn't suffer from wall or other scale effects.

- On page 21 of the report, EERC indicates that the catalyst used in the Baldwin and Coyote Station tests was supplied by Haldor Topsoe and the pitch was approximately 6mm. This pitch is smaller than what is typically used in a high dust SCR installation. Because the testing equipment was configured in an attempt to simulate a HDSCR environment, the results are thus suspect. In contrast, on page 22, EERC indicates that the catalyst used in the Columbia Station was Babcock Hitachi and the pitch was approximately 10 mm. Because the catalysts types and pitches were different in the Baldwin and Coyote tests versus the Columbia test, only the results of the Baldwin and Columbia tests can be compared. As the July 2008 Hartenstein report indicates, the full scale HDSCR installations at Baldwin Units 1 & 2 were commissioned in 2002 and 2003 and have since been in service for more than 45,000 hours without any of the problems indicated during the Baldwin Pilot Testing. Thus, even though the Coyote Station testing showed greater pluggage than at Baldwin Station, it is likely not representative of actual catalyst performance.

- The report does not indicate if screens were used to protect against popcorn ash deposition, which is the usual practice in a high dust SCR installation.

- The testing utilized a "pulse section," which was used to mimic a typical soot blower used to clean catalyst in a full-sized SCR installation. However, no details were provided as to how the effectiveness of this system may have compared to actual full-sized soot blowers.

- In a number of publications reviewed in this report, temperature is often cited as an important variable in the formation of catalyst deactivation. For instance, as several sources cited in this report indicate, if the temperature of the exhaust gas is below the gas phase or above the dew point, the likelihood of catalyst deactivation due to deposition of alkali and/or alkaline earth metals is greatly reduced. Although the report indicates that temperature was varied, it does not appear to investigate this issue.

- The report indicates that the catalyst plugging at all three stations was primarily due calcium sulfate and that XRD analysis identified $CaSO_4$ as a major phase and $Ca_3Mg(SiO_4)_2$ and $CaCO_3$ as minor phases. Consequently, sodium, consistently pointed to as the key catalyst deactivator by Minnkota, was not found by the report to significantly contribute to catalyst plugging. Thus, deactivation is a moot issue if the test catalyst was plugged (by calcium and sulfur rich materials) as a result of the ash from *both* the subbituminous and lignite fuels. Despite this apparent problem, there are a number of EGUs that burn subbituminous coals that have successfully run SCR systems.

- Although there are many issues noted with the configuration of this study, and that calcium and sulfur rich materials were noted as bing the dominant plugging materials, the report states on page 55 that, "[i]nstallations involving lignite fuels will need advanced cleaning techniques to handle the high sodium and high dust loads associated with burning most lignite fuels." Based on a number of problems raised herein, there does not appear to be any information present in the report that would justify this statement or any conclusion that SCR is infeasible for lignite-burning EGUs.

<u>Our Conclusions Regarding the 2004 EERC Slipstream Report</u>

We conclude that due to inconsistencies, problems, and unanswered questions regarding the design of the testing, this report provides little information that would be applicable to a determination of the technical feasibility of any SCR configuration. These issues aside, the fact that the testing was conducted to simulate a HDSCR configuration results in its inapplicability to LDSCR and TESCR configurations. Consequently, we believe that any conclusions that this report indicates the need for further testing for LDSCR and TESCR configurations are unjustified.

3.2 June 2008 North Dakota Preliminary BACT Determination

The June 2008 North Dakota Preliminary BACT Determination concludes that SCR in any configuration—HDSCR, LDSCR or TESCR—is not technically feasible for Milton R. Young. Below, we outline North Dakota's major concerns, observations, and conclusions. We do not cover portions of the determination which contrasts and compares various NOx control technologies other than SCR. Also, we do not critique much of North Dakota's determination, as we believe that the July 2008 Hartenstein Report, which we review in the next section, did an adequate job in that regard. We conclude that the information Mr. Hartenstein presents in addressing the 12 conclusions in North Dakota's June 2008 Preliminary BACT Determination is well documented and convincing.

North Dakota begins by acknowledging its burden to overcome the presumption of applicability required by EPA's NSR Manual.[14] However, North Dakota places great weight on potential differences between existing SCR installations and a cyclone boiler that burns North Dakota lignite. North Dakota's assessment first covers HDSCR, followed by a combined assessment of LDSCR and TESCR, which was very short and incomplete.

North Dakota's HDSCR Assessment

North Dakota investigates Minnkota's assertion that sodium constituents will poison the catalyst in a HDSCR configuration. It does this by calculating the mass loading of sodium on the catalyst for North Dakota lignite, Texas lignite, Wyoming PRB subbituminous coal, and PA bituminous coal. It concludes that North Dakota lignite will have a higher ash sodium content than other coals. It also concludes that no SCR installations existed on boilers that burned coal with a similar sodium ash content.

North Dakota was influenced by a report which concludes "the ash deposition behavior of the lignites from North Dakota is the most complex and severe of any coals in the world, and installation of catalysts for NOx reduction is going to be plagued with problems," and that "[a]lkali and alkaline earth sulfates are enhanced by cyclone-fired systems. The cyclone firing results in partitioning of the ash between bottom slag and the body of the boiler. The sulfate forming materials are more concentrated in the fly ash as a result of cyclone firing." [15]

North Dakota establishes a minimum 10,000 hour catalyst life as a threshold determinant of technical feasibility, by referencing several sources of typical catalyst guarantees. Although it noted that the Coyote pilot testing[16] was flawed, it concluded that the catalyst plugging at Coyote, which burns North Dakota lignite, was more rapid than at Baldwin, which burns PRB. North Dakota also concludes that the lack of deactivation data from the Coyote test indicated to it that additional pilot testing would be necessary.

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[14] Draft, October 1990, New Source Review Workshop Manual, Prevention of Significant Deterioration, and Nonattainment Area Permitting, page B18: "Deployment of the control technology on an existing source with similar gas stream characteristics is generally sufficient basis for concluding technical feasibility barring a demonstration to the contrary."

[15] Benson, Steven A., Energy and Environmental Research Center, Ash Impacts on SCR Catalytic Performance, University of North Dakota, Grand Forks, North Dakota 58202-9018.

[16] See our review of the November 2004 EERC Slipstream Report in Section 3.1.

North Dakota accepts Minnkota's claim that flue gas temperature variation at a HDSCR location would be a concern, noting various sources indicating that temperature variation may be out of range for a SCR installation. Due to this, it concluded that additional research, design and testing may be required.

North Dakota appears to have placed great weight on (1) Burns and McDonald SCR experience in its preparation of Minnkota's BACT assessment which found SCR to be technically infeasible and (2) Sargent & Lundy's experience in SCR design, when it recommended additional parametric pilot testing.

North Dakota acknowledges that some vendors indicated a high degree of confidence in a successful SCR installation at Milton R. Young, while it concluded that others were less optimistic. It stated that all responses indicated that additional testing was needed, the temperature variation problem discussed above must be resolved, and "make good" guarantees were not provided. North Dakota discounted the "optimistic" vendors, which included Alstom, Haldor Topsoe, and CERAM. We believe this criticism is misplaced. These vendors had a proven track record in SCR installations using fuels that are comparable in alkali and alkali earth metals (e.g., sodium, potassium) to North Dakota lignite. In addition, North Dakota's use of AP-42 as a source of a typical wood's sodium content in comparison to North Dakota lignite was misplaced. Wood ash may typically have a comparatively low sodium content, but it is high in potassium, which is a more potent alkali metal catalyst poison, as we discuss elsewhere in our report. North Dakota's conclusion that "experience with wood-fired boilers has questionable application to a boiler firing North Dakota lignite" is undocumented and without merit.

North Dakota then summarizes supplemental information provided by Minnkota. The applicable issues mainly involve Minnkota's concerns (covered elsewhere in North Dakota's BACT determination) that North Dakota lignite presents unique problems to a SCR installation. North Dakota acknowledges that EPA disagreed with many of these issues.

North Dakota summarizes its HDSCR determination by presenting 12 conclusions. We believe that the July 2008 Hartenstein Report adequately addresses most, if not all, of the concerns North Dakota raises in these conclusions.

North Dakota's LDSCR and TESCR Assessment

North Dakota only devotes 2-1/2 pages (page 55-57) of its 76 page June 2008 North Dakota Prelim BACT determination in consideration of the technical feasibility of LDSCR and TESCR configurations. It does not distinguish between LDSCR and TESCR configurations, despite the fact that the exhaust stream would additionally pass through a wet scrubber in a Milton R. Young TESCR configuration. North Dakota dismisses the fact that in either a LDSCR or TESCR configuration, the majority of the Particulate Matter (PM) would be removed by a properly maintained and operated ESP. It draws this conclusion by reference to the Minn-Dak lignite-fired boilers. North Dakota states that Minn-Dak had trouble complying with its PM limit because sodium compounds were not being captured by its air pollution control devices. North Dakota then apparently assumes that issue would be present in any North Dakota lignite-fired

boiler. North Dakota provides no evidence that anything associated with the Minn-DAK boilers or its air pollution control devices can be transferred to the Milton R. Young or any other North Dakota lignite-fired EGUs. North Dakota attempts to reinforce its position by stating that Minnkota provided evidence in its 11/9/2007 response to comments that sodium and potassium compounds were deposited downstream of the ESP on Unit 1. North Dakota then uses this information to conclude that catalyst deactivation remains an issue, apparently regardless of any real knowledge of the actual amount of sodium constituents present in the exhaust stream. We believe that North Dakota's determination that neither LDSCR nor TESCR are technically feasible for Milton R. Young was not based on a thorough review of the available information and was in fact wrongly decided.

Our Conclusions Regarding the June 2008 North Dakota Preliminary BACT Determination

The vast majority of North Dakota's SCR BACT determination was focused on HDSCR. We believe the July 2008 Hartenstein Report addresses most, if not all, of the concerns North Dakota raises regarding a HDSCR installation. As we have discussed in the beginning of our report, we believe that North Dakota's decision to make a 10,000 hour catalyst life a threshold determinant of technical feasibility is misplaced, as catalyst life should be considered a cost issue. We also conclude that North Dakota does not adequately address the many technical differences that distinguish a LDSCR or a TESCR configuration from a HDSCR configuration. Further, we conclude that North Dakota should have minimally determined that based on the information available to it, a TESCR installation at Milton R. Young is technically feasible.

3.3 July 2008 Hartenstein Report

This section covers a review of the July Hartenstein Report,[17] which concluded that LDSCR and HDSCR technology are both technically feasible for the Milton R. Young Station. Mr. Hartenstein starts by reviewing the successful history of SCR installations in Japan and Europe, and summarizes some of the design challenges that have long been overcome. He notes that TESCRs have been installed on many different applications throughout Europe, with normal expected catalyst lifetimes of 100,000 hours. Regarding one of the issues Minnkota frequently points to—plugging of catalyst—Mr. Hartenstein reports that in several HDSCR applications, although initial testing concluded that catalyst would rapidly plug, actual experience following installation proved that concern was unfounded.[18] Mr. Hartenstein notes that in a TESCR installation, the situation is dramatically less challenging because the flue gas downstream of a wet scrubber, which a TESCR is exposed to, is extremely clean compared to what the catalyst is exposed to in a HDCSR upstream of the ESP. Mr. Hartenstein cites to Minnkota's own data that downstream of an ESP and a wet scrubber in excess of 99% of the fly ash is removed in the ESP and between 90% and 95% of SO_2 is removed in the wet scrubber, thus leaving very little if anything in the flue gas that is critical for catalyst deactivation. Mr. Hartenstein states that in a TESCR installation, the flue gas has gone through its dew point after being cooled to saturation while passing through the wet scrubber. Consequently all condensable catalyst poisons,

[17] Feasibility of SCR Technology for NOx Control Technology for the Milton R. Young Station, Center, North Dakota, Expert Report of Hans Hartenstein, on Behalf of the, United States Department of Justice, July 2008.
[18] See the July 2008 Hartenstein Report, page A-15, concerning Dynergy's Baldwin Station and Luminant's Sandow Station.

including the alkali and earth alkali salts that Minnkota frequently point to as catalyst poisons, will inevitably have condensed and will have been mostly removed by the wet scrubber. In a wet scrubber all water soluble compounds including water soluble alkali sulfates, phosphates and carbonates as well as all residual alkali vapors are virtually quantitatively removed as a result of their extremely high water solubility. Therefore, compared to a HDSCR, TESCR catalyst are confronted with less than 0.5% of the particulate matter and less than 5 - 10% of the acid gases, vapors and other water soluble compounds, which cause catalyst deactivation. Consequently, the catalyst deactivation rate is correspondingly slower.

Regarding a 2005 paper, [19] Mr. Hartenstein makes a significant observation: The Coyote Pilot Testing and the Baldwin Pilot Testing[20] used the same pilot test reactor equipped with the same Haldor Topsoe catalyst. Based on the earlier Baldwin Pilot Test results, the technical feasibility of HDSCR at Baldwin's cyclone-fired Units l & 2 burning 100% PRB would have been at least highly questionable and a BACT determination similarly conducted as the one by the Department for the M.R. Young Station would most likely have reached the same conclusion as was reached for the M.R. Young Station, namely that the SCR is technically infeasible for retrofit at the Baldwin Energy Center. However, the full scale HDSCRs at Baldwin Units 1 & 2 were commissioned in 2002 and 2003 and have since been in service for more than 45,000 hours without any of the problems indicated during the Baldwin Pilot Testing. Thus, the oft-cited pilot testing conducted at Coyote Station, even though it showed greater pluggage than at Baldwin Station, is likely not representative of actual catalyst performance.

Mr. Hartenstein then notes communications with CERAM indicated it was premature to assume that there was a fatal flaw for the use of high duct SCR behind cyclones burning North Dakota lignite and that these concerns are similar to those used 10 years ago against the application of PRB HDSCR applications.

Mr. Hartenstein reviews the June 2008 North Dakota Preliminary BACT Determination's 12 conclusions. A brief summary of his views on each of these conclusion follows:

- *Variability of Fuel Composition.* Mr. Hartenstein concludes that variability of constituents in coals is common and notes that he is unaware of a single case in which fuel variability of any type was a reason for concluding that an SCR installation was infeasible.

- *Results of the Coyote Pilot Testing.* Mr. Hartenstein notes that despite the facts that North Dakota itself concluded the pilot testing was ill-designed and did not provide much useful data, and that several catalyst manufacturers were then willing to provide guarantees, North Dakota still erroneously concluded that "the Coyote testing demonstrates to the Department that North Dakota lignite firing will have more severe effects (plugging and catalyst deactivation) than units firing sub-bituminous coal when the same design is employed."

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[19] Benson, A. J. D. Laub, C. R. Crocker, J. H. Pavlish, SCR catalyst performance in flue gas derived from subbituminous and lignite coals", Fuel Processing Technology 86 (2005) pages 577 - 613, 2005.
[20] See our review of the November 2004 EERC Slipstream Report in Section 3.1.

- *Soluble Sodium.* Mr. Hartenstein was critical of North Dakota's conclusion "the combustion of (North Dakota) lignite produces soluble sodium compounds, which cause more severe catalyst deactivation than insoluble sodium compounds." Mr. Hartenstein concludes this concern is unfounded because as one experienced catalyst vendor stated, "sodium is not a poison to catalyst at SCR operating temperatures." Mr. Hartenstein concludes that sodium would have to be present in either gas or liquid phase, and SCR operating temperatures preclude either.

- *Differences in Flue Gas Composition.* Mr. Hartenstein criticizes North Dakota's conclusion that North Dakota lignite flue gas is unique, as North Dakota likely does not have flue gas compositional data from all other SCR installations.

- *Experience of Burns and McDonnell and Sargent and Lundy.* North Dakota concludes that both Burns and McDonnell and Sargent & Lundy have extensive experience with the design and operation of SCR systems and so their conclusions should carry great weight. Mr. Hartenstein concludes that neither firm had much applicable experience.

- *Development Stage of HDSCR.* North Dakota concludes that a North Dakota lignite SCR installation would require additional data from bench scale testing. Mr. Hartenstein opines that no catalyst manufacturer and/or SCR system supplier would turn down additional bench scale and/or pilot testing as it provides for risk free research paid for by others. He further concludes that, even if HDSCR would not be economically viable, LDSCR or TESCR certainly would be, and are technically feasible as clearly indicated by the multitude of installations and statements of SCR catalyst manufactures.

- *Temperature Variations.* Mr. Hartenstein agrees with North Dakota's concern that "the temperature variation of the flue gas entering a HDSCR will adversely affect the performance and must be resolved for successful application of this technology." Mr. Hartenstein points to statements made by Babcock and Wilcox, the boiler supplier, concerning mitigating measures that could be implemented. [We note this is a cost, not a technical feasibility issue.]

- *Catalyst Erosion.* North Dakota expresses concern that catalyst erosion issues have not been resolved. Mr. Hartenstein disagrees and cites to much of his aforementioned examples of successful SCR installations that burn coals with much higher ash contents.

- *Catalyst Poisoning, Blinding and Plugging.* Mr. Hartenstein disagrees with North Dakota's conclusion that North Dakota lignites will cause blinding and plugging of catalyst, as that conclusion rests on the previously discredited Coyote pilot testing. Mr. Hartenstein cites to catalyst vendor guarantees and other statements of technical feasibility. Further, Mr. Hartenstein cites to catalyst washing, rejuvenation and regeneration processes that are commercially available and have been successfully used in the U.S. as well as in Europe for more than a decade.

- *Lack of Pilot Scale Testing Data.* Mr. Hartenstein opines that North Dakota's statements concerning the need for pilot testing seem to be incompatible with other statements North

Dakota has made concerning its firm conclusion that North Dakota lignite would plug and poison catalyst. Mr. Hartenstein refutes these statements using previously made arguments.

- *Lack of Vendor Guarantees.* Mr. Hartenstein refutes North Dakota's claim that vendors will not provide guarantees without further pilot testing, citing to CERAM and Haldor Topsoe statements to the contrary.

In summary, Mr. Hartenstein states that North Dakota made numerous factually incorrect claims, conclusions and statements, the most significant of which include:

- The conclusion that HDSCR is not technically feasible is based on the data obtained from the ill-designed HDSCR Coyote Pilot Testing.

- The statement that Bums & McDonnell and Sargent and Lundy have extensive experience with the design and operation of SCR systems.

- The claim that vendors cannot guarantee SCR system performance for M.R. Young Station.

Our Conclusions Regarding the July 2008 Hartenstein Report

We conclude that Mr. Hartenstein refutation of the June 2008 North Dakota Preliminary BACT Determination's 12 conclusions was well supported. In particular, we believe that Mr. Hartenstein's conclusions regarding the lack of useful information from the Coyote Pilot Testing (the November 2004 EERC Slipstream Report), the fundamentally non-unique nature of North Dakota lignite exhaust gas, and the availability of vendor guarantees, are particularly salient.

3.4 May 2009 North Dakota SCR BACT Feasibility Report

This section covers a review of the May 2009 North Dakota SCR BACT Feasibility Report,[21] which concludes that high dust SCR is infeasible but that low dust and tail-end SCR are feasible. It also cites to a number of successful SCR installations that burn biomass.

The May 2009 North Dakota DEQ SCR BACT Feasibility Report ("the 2009 BACT Report") identifies the two key considerations in determining if a particular control technology is technically feasible: if that control is "available" and if it is "applicable." North Dakota DEQ states that a control is considered "available if it can be obtained through commercial channels or is otherwise available within the common sense meaning of the word. Similarly, a control is considered "applicable if it can reasonably be installed and operated on the source type under consideration.[22] North Dakota DEQ does not present any information that SCR is not available under this definition. All the issues under review that are pertinent to the technical feasibility of SCR on North Dakota lignite EGUs fall under the second test—"applicability."

[21] Selective Catalytic Reduction (SCR) Technical Feasibility for M.R. Young Station, contained in the 2010 RH SIP as Appendix B.6.
[22] See pages 3 and 4 of the May 2009 North Dakota SCR BACT Feasibility Report.

Regarding applicability, North Dakota DEQ notes that absent a successful deployment on the same or similar source type, deployment on a source *with similar gas stream characteristics*, is generally sufficient basis for concluding technical feasibility barring a demonstration to the contrary. Unless significant differences between source types exist that are pertinent to the successful operation of the control device, the control option is presumed to be technically feasible unless the source can present information to the contrary. The key objection by Minnkota and other North Dakota EGU operators has been that due to the presence of certain alkali and/or alkaline earth metals, North Dakota lignite is unique among all coals and lignites, rendering boilers that fire these lignites unsuitable for the operation of SCR due to poisoning and/or deactivation of the SCR catalyst, regardless of SCR configuration.[23] Therefore, the key question on applicability, and consequently technical feasibility, is whether any SCR configuration has been installed on any other boiler with similar gas stream characteristics. This includes SCR configurations (e.g., LDSCR or TESCR) in which these alkali and/or alkaline earth metals have been so reduced they do not poison and/or deactivate catalyst.

North Dakota DEQ Assesses the Technical Feasibility of High Dust SCR

North Dakota DEQ received a number of comments concerning the applicability of HDSCR to North Dakota lignite EGUs. Comments applicable to this report mainly concern those relating to the ability of alkali and/or alkaline earth metals to deactivate SCR catalyst and concerns that the temperature of the exhaust gas may not be suitable for a HDSCR installation. Much of the consideration given by North Dakota DEQ concerns whether the catalyst would provide at least 10,000 hours of life (which equates to 1.14 years of continuous operation), which it has imposed as a threshold consideration for BACT.[24]

As we discuss later in this report, however, various on-site maintenance techniques are available to at least partially mitigate the plugging and fouling of catalyst. However, North Dakota DEQ apparently does not consider them in this analysis and assumes that whatever mass of alkaline poison in the exhaust will in fact adhere to the catalyst. In addition, catalyst rejuvenation is a proven technique for restoring catalyst effectiveness. Both of these issues should be thought of as maintenance issues that can be monetized to capital and annual operating costs. In other words, the fact that a facility must perform maintenance should not be viewed as test of a particular technology's technical feasibility for either BACT or BART but should be included in that technology's cost-effectiveness calculation.

North Dakota DEQ considers these comments and concludes that in a HDSCR configuration, "Recent testing by Kling and Zheng suggest a low probability of achieving successful application of HDSCR technology by MRYS. The high concentration of sodium and potassium in the flue gas will rapidly deactivate the catalyst. The results suggest much less than 10,000

[23] As we discuss elsewhere in this paper, we also present evidence that the issue of alkali poisoning and/or deactivation can be viewed as a manageable maintenance issue.

[24] On page 29, North Dakota indicates that it created this threshold in its June 2008 Preliminary Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2. In that document, on page 32, North Dakota cites to minimum catalyst life ranging from 10,000 to 30,000 hours based on EPA's Control Cost Manual.

hours of catalyst life which the Department believes is necessary for successful application of HDSCR."[25] North Dakota concludes that a HDSCR configuration is not technically feasible for EGUs burning North Dakota lignite. We believe this conclusion by North Dakota is unjustified by those studies. As we indicate below, due to limitations in the methodology, testing equipment, and focus, the cited Kling and Sheng studies cannot be used to predict a minimum SCR catalyst life for North Dakota lignite EGUs in a high dust configuration.

North Dakota DEQ also concludes that pilot testing of up to 24 weeks at a cost of up to $400,000 would be required to properly determine if the exhaust temperature could be brought into the proper range for SCR operation, and that the NSR manual indicates that a company is not required to undertake such testing to learn how to apply a control technology. We treat these temperature issues in our review of the July 2009 North Dakota SCR BART Report, in which North Dakota discusses them in more detail.

We reviewed the Kling and Zheng studies.[26] The Zheng study concerned laboratory and bench scale studies of catalyst deactivation in the presence of potassium aerosols. There were two main conclusions of the study:

- A slight deactivation (about 10%) was observed for catalyst plates exposed to a layer of KCl particles at 350˚ C for 2,397 hours, and that no deactivation was found for catalyst plates exposed for 2,970 hours to fly ash (consisting mainly of KCl and K_2SO_4) collected from an SCR pilot plant installed on a straw-fired power plant.

- A fast deactivation was observed for catalysts exposed to pure KCl or K_2SO_4 aerosols at 350˚ C in the bench-scale reactor.

Regarding the Zheng study, we make the following observations:

- Both the laboratory and bench scale tests were concerned with investigating SCR catalyst deactivation in response to potassium constituents, not the sodium constituents that Minnkota and others frequently state make the North Dakota lignites uniquely unable to support the installation of SCR. As a commenter notes, "Crespi has provided data that suggests potassium oxide is approximately twice as potent a catalyst deactivation chemical on a molar basis (1.3 times on a mass basis) than sodium oxide."[27] Therefore, the test results cannot be used to establish a minimum HDSCR catalyst life for North Dakota lignite. This is because the North Dakota lignites, have been distinguished from other lignites and coals due to their high *sodium* content and thus even discounting the

[25] See page 19 of the May 2009 North Dakota SCR BACT Feasibility Report.
[26] Kling, Asa; Andersson, Chester; Myringer, Ase; Eskilsson, David; Jaras, Sven G.; Alkali deactivation of higher dust SCR catalysts used for NOx reduction exposed to flue gas from 100 MW-scale biofuel and peat fired boilers: Influence of flue gas composition; Applied Catalysis; 2007. Zheng, Yuanjing; Jensen, Anker Dega; Johnsson, Jan Erik; Thogersen, Jaokim Reimer; Deactivation of V205 - W03 - Ti02 SCR catalyst at biomass fired power plants; Elucicdation of mechanisms by lab - and pilot-scale experiments; Applied Catalysis; 2008.
[27] See page 11 of the May 2009 North Dakota SCR BACT Feasibility Report. The citation is: Crespi, Mario; Porle, Magnus; Larsson, Dr. Ann - Charlotte; La Civita, Raffaela; Nielsen, Anders Rooma; The influence of biomass burning in the design of an SCR installation.

other limitations we cite, the Zheng study would therefore overestimate catalyst deactivation since it focused on potassium.

- Both the laboratory and bench scale tests were conducted using a synthetic exhaust gas that was not directly correlated to any real world EGU exhaust stream, certainly not any EGU that burns North Dakota lignite. In other words, the purpose of the tests was to determine if potassium constituents could deactivate SCR catalyst under certain chemical and physical conditions. Comments that cite to the Zheng study do not specifically tie it to the specific chemical and physical conditions of the exhaust of any EGU that burns North Dakota lignite.

Regarding the Kling study, we make the following observations:

- The instrument used to measure the alkali and/or alkaline earth metals content of the flue gases in the testing, an situ alkali chloride monitor (IACM), measured the sum of the sodium and potassium chloride concentrations and could not differentiate between the two species. Therefore, as with the Zheng report, the Kling test results cannot be used to establish a minimum HDSCR catalyst life.

- The Kling study acknowledges two main limitations which preclude it from being used to directly draw conclusions concerning whether the catalyst in a full-sized SCR installation that burns North Dakota lignite would be able to satisfy North Dakota's 10,000 hour deactivation threshold.

    - First, the study notes that "[t]he decrease in sulphur content in the catalyst material, during exposure of the catalyst samples in the low sulphur gas flow, was probably a part of the catalyst deactivation during the biofuel combustion. Studies on regeneration of catalyst deactivated during biofuel combustion have shown that sulphation, exposure of the samples to gaseous SO_2, increased the activity of the catalyst samples from a relative activity of about 50% up to a relative activity of about 80%."[28]

    - Second, study notes that, "[e]xposure of this kind of short samples gives a larger deactivation compared to a full-length catalyst. That is mainly a consequence of turbulence at the inlet of the catalyst, before the laminar flow is attained." Also, "[t]he deactivation of the catalyst samples cannot directly be compared with the deactivation of a full-length catalyst. The poisonous components accumulate at the inlet of the catalyst and the catalyst deactivation will be higher on the short SCR samples."[29] Similar concerns regarding the impact of the scale of the testing on the results have been raised concerning the legitimacy of the 2004 EERC Slipstream Report on the Coyote, Columbia and Baldwin Facilities.

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[28] Kling, Asa; Andersson, Chester; Myringer, Ase; Eskilsson, David; Jaras, Sven G.; Alkali deactivation of higher dust SCR catalysts used for NOx reduction exposed to flue gas from 100 MW-scale biofuel and peat fired boilers: Influence of flue gas composition; Applied Catalysis; 2007. See page 249.

[29] *Ibid.* See pages 241 and 243.

- The main conclusions of the Kling study were (1) that increased alkali and/or alkaline earth metals particle accumulation on the catalysts correlated to increased catalyst deactivation, and (2) that smaller sized alkali particles were more likely to accumulate on the catalyst than larger sized particles. However, because as stated above, the study could not discriminate between the relative contributions of the sodium and potassium fractions, neither of these conclusions can be directly applied to distinguish North Dakota lignite from other fuels that have higher potassium contents. Interestingly, the study did note that, "[a]n increased amount of vanadium in the catalyst material decreased the catalyst deactivation rate significantly."[30] However, the use of high vanadium catalyst has not been investigated by Minnkota or others as a means to address the alkali and/or alkaline earth metals content issue.

North Dakota Assessed the Technical Feasibility of Low Dust and Tail-End SCR

North Dakota approached its assessment of the technical feasibility of LDSCR and TESCR by noting that there is no direct experience with these technologies for EGUs that burn North Dakota lignite. Therefore, it must assess the flue gas characteristics of the Milton R. Young facility in comparison to other facilities that have successfully employed these technologies.

North Dakota first assessed a TESCR configuration, in which the SCR would be located after the ESP and the scrubber. Using data supplied by Minnkota, North Dakota reviewed August 2007 and May 2008 stack testing performed at the Milton R. Young Unit 2 and noted that *the ESP and scrubber remove greater than 99% of the total sodium and potassium mass.*[31] North Dakota then calculated that the submicron sodium sulfate plus potassium sulfate emission rate would be less than 2.2 mg/Nm^3 and the emission rate of sodium and potassium sulfate less than 0.26 micrometers in size would be approximately 1.0 mg/Nm^3. Following this, North Dakota conservatively estimated that the total emission rate for sodium and potassium sulfate combined that is less than or equal to 0.1 micrometers in size is 0.98 mg/Nm^3 of which 0.78 mg/Nm^3 is sodium sulfate. North Dakota then compared these data to the data in the Zheng and Kling reports discussed above and conservatively concluded that the rate of catalyst deactivation for a North Dakota lignite SCR installation would be substantially slower than reported by the Zheng and Kling studies.[32]

Following this, North Dakota assessed a LDSCR configuration, in which the SCR would be located after the ESP but before the scrubber. North Dakota notes that multiple sources indicate that an ESP can remove 96 – 98% of the submicron particulate matter in the exhaust.[33] North

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[30] *Ibid.* See page 250.

[31] See page 22 of the May 2009 North Dakota SCR BACT Feasibility Report.

[32] In so doing, North Dakota noted certain limitations in the Zheng and Kling studies that would cause the reported deactivation rates to be lower if applied to North Dakota lignite exhaust. This includes (1) not considering that potassium is a more potent catalyst deactivator than sodium and that the chlorides which dominate biomass burning are more potent than the sulfates which dominate lignite/coal burning, (2) observations by Kling that the testing in his study likely resulted in a higher deactivation rate due to the scale of the bench equipment in comparison to a full sized SCR installation, and (3) that the loading in a tail-end or low dust SCR configuration would likely be lower than examined in the Zheng and Kling studies.

[33] This removal efficiency range of submicron particles by a properly maintained and operated ESP is too low. Submicron particles are efficiently removed in ESPs due to the efficiency of diffusion charging of such particles.

Dakota also noted that even without the scrubber, the submicron loading would still be considerably less than considered in the Zheng and Kling studies, and consequently, the catalyst deactivation of a LDSCR configuration should be lower than in those studies.

North Dakota noted that three catalyst vendors, CERAM Environmental, Haldor Topsoe, and Babcock Power indicated that a TESCR installation was technically feasible and were apparently willing to provide catalyst guarantees for a TESCR installation at Milton R. Young. As we discuss later in this report, these catalyst vendors later placed additional restrictions on their commitments. North Dakota then noted that although no coal-fired EGUs with similar alkali and/or alkaline earth metals concentrations have installed and run SCR, at least four biomass fired boilers in the U.S., with similar expected (but unverified) alkali concentrations, have installed and successfully run TESCR or LDSCR for a number of years and in fact lists four of them.[34]

Based upon all of the available evidence reviewed, North Dakota concluded that both LDSCR and TESCR were technically feasible at Milton R. Young. Later in our report, we review the factors that led North Dakota to later change that conclusion.

Our Conclusions Regarding the May 2009 North Dakota SCR BACT Feasibility Report

The salient points from the May 2009 North Dakota SCR BACT Feasibility Report can be summarized as follows:[35]

- Potassium, sodium, and other alkali metals are capable of severely deactivating SCR catalyst and shortening its service life.[36]

- Potassium constituents have a 1.1 - 1.3 times greater potential (on a mass basis) to deactivate catalyst than sodium constituents.

- Submicron sized constituents of alkali metals are the dominant size fraction which causes catalyst deactivation.

- European experience in biomass fired boilers indicates that potassium is the dominant alkali catalyst poison and that it occurs in approximately the same or greater amounts in the exhaust of successfully deployed SCR systems in comparison to the exhaust at Milton R. Young.

[34] See page 28 of the May 2009 North Dakota SCR BACT Feasibility Report.
[35] Note that our comments are based on how we would have judged the same information available to North Dakota at the time of its a May 2009 North Dakota SCR BACT Feasibility Report. As we discuss later, additional information (some of it research and industry experience that occurred later in time) further refines our conclusions affirming the feasibility of the control.
[36] As we discuss elsewhere, various maintenance techniques are available to (1) partially mitigate these effects onsite and (2) to rejuvenate catalyst to 100% effectiveness offsite. Thus, catalyst deactivation can be viewed as an operating expense and not a limiting factor in the technical feasibility of SCR.

- Based on a conservative use of the data in the Zheng and Kling reports, it appears that LDSCR and TESCR configurations would meet at least the 10,000 hour catalyst life set by North Dakota as a threshold for BACT acceptability.

- At the time of this report, three catalyst vendors concluded that a TESCR configuration was technically at Milton R. Young and apparently willing to provide catalyst guarantees.

- At least four biomass boilers, which based on European data are expected to have similar total alkali concentrations similar to North Dakota lignite, have operated SCR for a number of years in LDSCR or TESCR configurations.

We agree that North Dakota made the correct determination that LDSCR and TESCR configurations are technically feasible for Milton R. Young. However, although catalyst fouling and deactivation would certainly pose a greater problem in a HDSCR configuration, we do not believe that enough information was presented to conclude that a HDSCR configuration is technically infeasible for EGUs that burn North Dakota lignite, even considering North Dakota's 10,000 hour catalyst life threshold.

3.5 July 2009 North Dakota SCR BART Report

This section covers a review of the July 2009 North Dakota SCR BART Report.[37] Although the July 2009 North Dakota SCR BART Report focuses on BART in lieu of BACT, from a technical standpoint it presents similar data and arguments in comparison to the May 2009 North Dakota SCR BACT Feasibility Report. We note, however, that the discussion concerning a HDSCR configuration was more detailed and presented some new information, which we discuss below. North Dakota's conclusions that a HDSCR configuration was not technically feasible, but that LDSCR and TESCR configurations are technically feasible remained unchanged from those in its May 2009 North Dakota SCR BACT Feasibility Report.

<u>North Dakota Assesses the Technical Feasibility of High Dust SCR</u>

In comparison to its May 2009 North Dakota SCR BACT Feasibility Report, North Dakota presented additional information to bolster its position that a HDSCR configuration is not technically feasible for the Milton R. Young facility. This consists mainly of USGS and other sources of coal sample data, and AP-42 PM emission factors for various furnace/coal combinations. North Dakota used this information to calculate the emission rates and various ratios for alkali constituents of North Dakota lignite, Texas lignite, Wyoming PRB and Pennsylvania Bituminous coals for a cyclone furnace similar to that used at Milton R. Young. Based on this information, North Dakota considered the potential catalyst deactivation rates of these coals if burned in a cyclone furnace. We are unable to judge this information, as North Dakota has not disclosed how it has calculated the lb/dscf and lb/wscf emission rates for sodium oxides (Na_2O) and for the selected combined alkali and alkali earth oxides ($Na_2O+CaO+MgO+K_2O$), which are key parameters in its conclusion that "the sodium oxide

[37] Best Available Retrofit Technology Selective Catalytic Reduction Technical Feasibility Analysis for North Dakota Lignite, July 2009, Division of Air Quality North Dakota Department of Health 918 E. Divide Avenue Bismarck, North Dakota. Contained in the 2010 RH SIP as Appendix B.5.

loading in the flue gas for the North Dakota lignite-fired unit would be nearly 24 times (on a lb/wscf basis) that of a cyclone unit burning PRB subbituminous coal," and "[t]he estimated combined loading of catalyst deactivation constituents sodium oxide, calcium oxide, magnesium oxide and potassium oxide is more than eleven times that of PRB subbituminous coal-fired cyclone units."[38] North Dakota discussed the same studies by Zheng, Kling, and Crespi, and the flue gas temperature concern discussed in its May 2009 North Dakota SCR BACT Feasibility Report. North Dakota concluded that a HDSCR configuration presents significant problems that would require additional research and testing before it could be properly designed.

North Dakota asserted that the temperature in Unit 1 and 2 of the Milton R. Young boilers varies outside of the range of typical SCR catalyst, concluding that "additional research, design and testing may be required before the temperature problem could be overcome for cyclone units."[39] In other words, North Dakota viewed this as a potential threshold decision point in determining the technical feasibility of a HDSCR configuration.

North Dakota began this discussion by citing to EPA's 2002 Control Cost Manual (CCM) statement that the optimum temperatures for the SCR process range from 480°F to 800°F (250°C to 427°C) and this statement from the CCM:

> The relationships between flue gas temperature, catalyst volume, and NOx removal are complicated functions of the catalyst formulation and configuration. The physical and chemical properties of each catalyst are optimized for different operating conditions. For a given catalyst formulation, the required catalyst volume and/or temperature range can even change from one manufacturer of the catalyst to another. The selection of catalyst, therefore, is critical to the operation and performance of the SCR system.

North Dakota concluded, "This complicated relationship suggests that additional research, design and testing may be required before the temperature problem could be overcome for cyclone units." We acknowledge that the 2019 revision to the SCR chapter of the CCM[40] also includes the above statement. However, just above that statement, the CCM presents Figure 2.2, which is a graph of the NOx removal efficiency as a function of temperature for a typical metal oxide catalyst. This graph makes it clear that although there is an optimum window of catalyst efficiency of perhaps 700 – 780°F, the catalyst can operate well outside of this range albeit with reduced catalyst efficiency.

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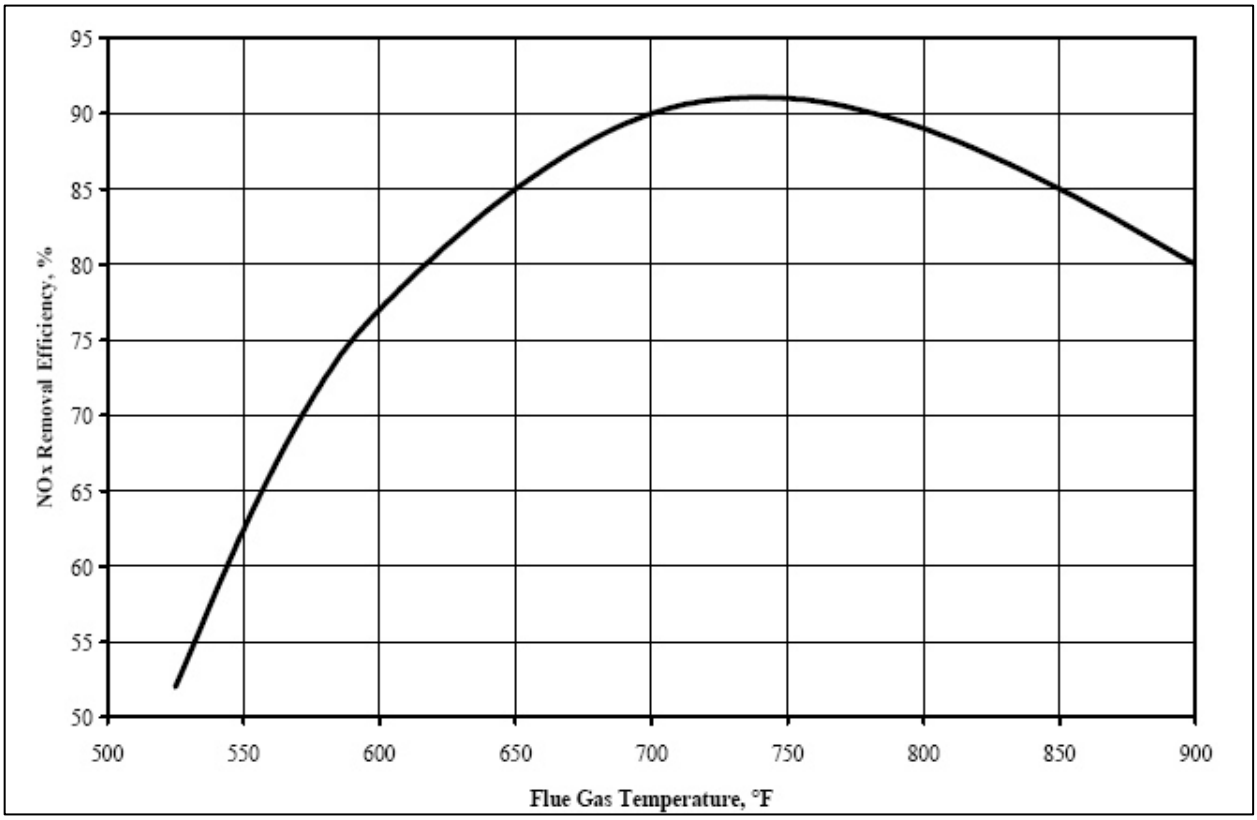
[38] *Ibid.,* page 10.
[39] *Ibid.,* page 13.
[40] EPA Control Cost Manual. Section 4, Chapter 2 Selective Catalytic Reduction, John L. Sorrels Air Economics Group Health and Environmental Impacts Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC 27711, David D. Randall, Karen S. Schaffner, Carrie Richardson Fry RTI International Research Triangle Park, NC 27709, June 2019. See pdf page 20.

Figure 1. NO_x Removal versus Temperature[41]



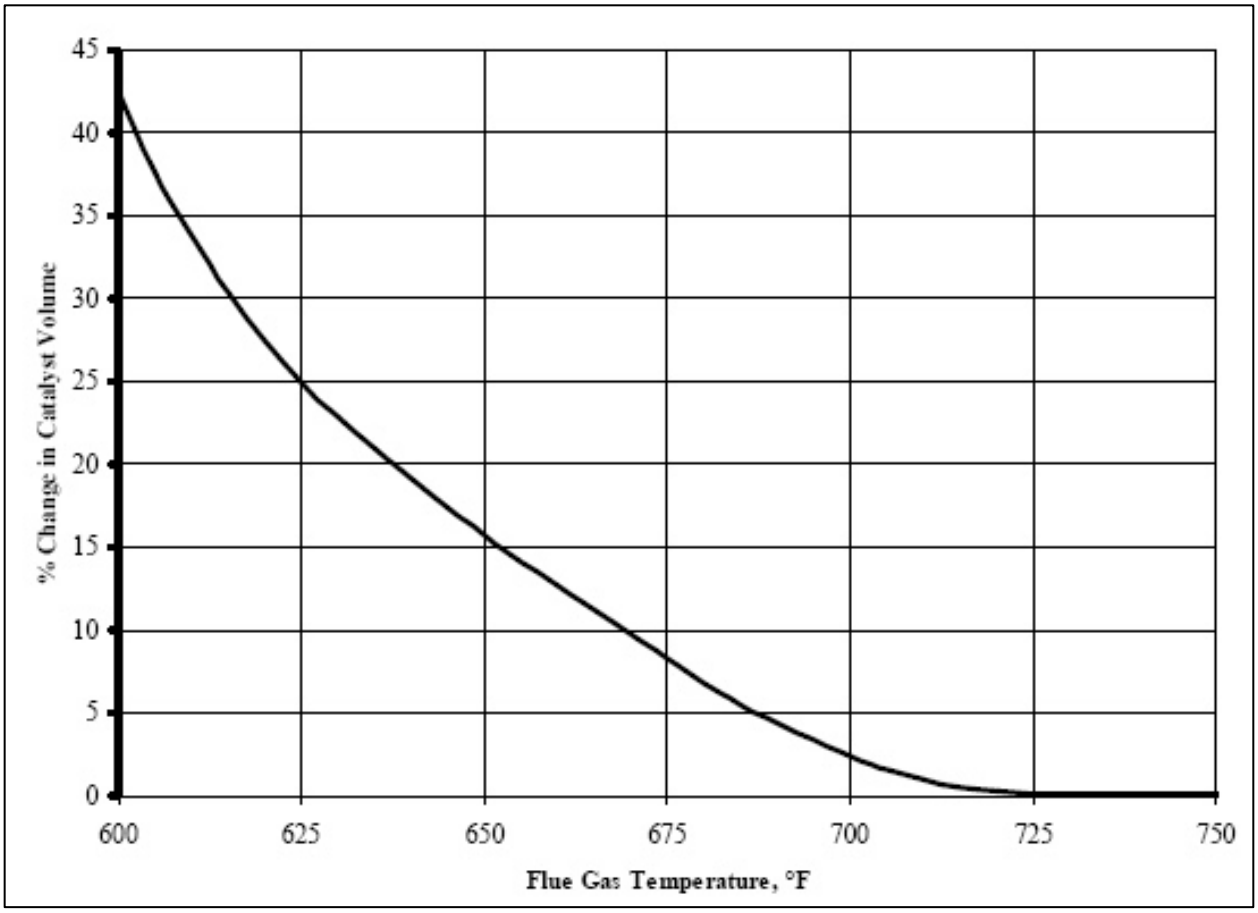
The CCM notes this effect not as a SCR feasibility issue, *but as a design and cost issue*. For instance, it goes on to state (just prior to the statement North Dakota reproduced above):[42]

> As flue gas temperature approaches the optimum, the reaction rate increases and less catalyst volume achieves the same NOx removal efficiency. Figure 2.3 [presented below] shows the change in the required catalyst volume versus temperature. There is approximately a 40 percent decrease in the required catalyst volume as flue gas temperature increases from 600°F (320°C) to the optimum range, 700 to 750°F (370 to 400°C). This decrease in catalyst volume also results in a significant decrease in capital cost for the SCR system. Less catalyst also results in a decrease in annual operation and maintenance costs. For example, the system pressure drop would be lower, which would reduce the additional electricity needed to run the induced draft (ID) fan. The net effect on catalyst replacement costs is uncertain; although the volume of catalyst replaced would be smaller, deactivation may occur more frequently since the quantity of

[41] Citation to the origin of Figure 2.2, in the 2019 EPA Control Cost Manual: Rosenberg, H.S., and J. H. Oxley. Selective Catalytic Reduction for NOx Control at Coal-fired Power Plants. ICAC Forum '93, Controlling Air Toxics and NOx Emissions, Baltimore, MD, February 24–26, 1993.
[42] 2019 SCR revision to the Control Cost Manual. See pdf page 20.

materials in the emission stream responsible for plugging and poisoning would not be reduced.

Figure 2. Change in Catalyst Volume vs. Temperature[43]



Therefore, more or less catalyst volume is required in the SCR design, depending on the temperature range of the exhaust. In addition, control of HDSCR temperature (both too high and too low) is well known to SCR system suppliers and ready made solutions have been offered for some time, and even employed in China.[44] Commonly, economizer flue gas and water heat absorption regulation is used to prevent SCR exhaust temperature from being too high or too low. Regarding this, the Control Cost manual states:[45]

> When the economizer outlet flue gas temperature decreases because the plant is operating at reduced loads, the temperature can be raised using an economizer bypass.

[43] Citation to the origin of Figure 2.3, in the 2019 EPA Control Cost Manual: Electric Power Research Institute (EPRI). Technical Feasibility and Cost of Selective Catalytic Reduction (SCR) NO x Control. EPRI GS-7266, Final Report, May 1991.
[44] See https://iopscience.iop.org/article/10.1088/1755-1315/233/5/052005/meta.
[45] EPA Control Cost Manual. Section 4, Chapter 2 Selective Catalytic Reduction. See pdf page 48.

> The economizer bypass duct generally has a modulating damper to regulate the amount of hot bypass gas flow to be mixed with the cooler economizer outlet flue gas. The lower the boiler load, the more this damper opens, thus admitting more hot gas. The economizer outlet duct also needs a modulating damper to provide enough backpressure to allow the required volume of gas to flow through the bypass. The main design considerations for an economizer bypass involve maintaining the optimum gas temperature and ensuring uniform mixing of the two gas streams prior to entering the SCR reactor.

These systems can be used to keep the SCR temperature within its optimum range even when the load drops to 50%. For instance, Babcock and Wilcox offers its V-Temp Economizer System for Optimized SCR Temperature Control.[46] Importantly, these systems have been proven to work and any engineering and testing is typically performed as a part of the SCR system design phase. In his July 2008 Report, Mr. Hartenstein also noted that solutions to this problem are available: "the temperature variation problem, which Babcock & Wilcox indicated can be technically resolved by incorporating the appropriate and necessary measures for the modification of the boiler's backpass and possibly the lignite pre-drying system[86], is no reason to determine that the SCR technology is technically infeasible for cyclone-fired units burning North Dakota lignite." As Mr. Hartenstein indicates, Babcock and Wilcox is the original manufacturer of the Milton R. Young boilers.

> Footnote to Mr. Hartenstein's remarks:
>
> 86. E-mail from Steve Moormann (Babcock &Wilcox) to Robert Blakley (Burns & McDonnell) dated 07/18/07.

Thus, HDSCR temperature regulation is not a threshold technical feasibility issue.

Following its SCR temperature discussion, North Dakota reviewed the BART Guidelines' discussion regarding whether a control is considered "available" for purposes of BART review but tempers that concept by stating that technical feasibility also includes consideration of whether that technology can be reasonably deployed. North Dakota concluded its HDSCR discussion by reviewing all the issues that have been cited as contributing to the plugging and/or deactivation of catalyst for EGUs that burn North Dakota lignite.

North Dakota Assessed the Technical Feasibility of Low Dust and Tail-End SCR

The discussion North Dakota presented in its July 2009 North Dakota SCR BART Report concerning the feasibility LDSCR and TESCR configurations is similar to what it presented in its May 2009 North Dakota SCR BACT Feasibility Report, including the Zheng, Kling, and Crespi citations. As with its May 2009 North Dakota SCR BACT Feasibility Report, North Dakota

[46] See https://www.babcock.com/en/products/-/media/edfae197306c4105bb1cf9d3c3fc20ef.ashx. Also see: https://www.emerson.com/documents/automation/case-study-emerson%E2%80%99s-ovation-scr-optimization-helps-constellation-energy%E2%80%99s-brandon-shores-save-200-000-in-nox-credits-en-67518.pdf, and https://www.ge.com/power/services/boilers/upgrades/economizer-outlet-gas-temp

concluded that both LDSCR and TESCR are technically feasible for boilers combusting North Dakota lignite that are subject to BART requirements.

3.6 July 2009 Microbeam Report

In this section we review the July 2009 Microbeam report which basically presents the results of exhaust stream sampling and analyses at various points in the pollution control train at Milton R. Young.[47] The Microbeam report and the July 2009 North Dakota BART Report were conducted at approximately the same time. The North Dakota BART report concludes that HDSCR is infeasible but that LDSCR and TESCR are feasible. We believe that the sampling and analyses reviewed by the July 2009 Microbeam report had the potential to directly address the first fundamental question regarding North Dakota lignite SCR technical feasibility: (1) What is the mass loading of alkali and/or alkaline earth metals a LDSCR and a TESCR would experience at a North Dakota lignite fueled EGU. Microbeam itself apparently recognized this opportunity, as on page 3 it listed one of its objectives to "provide an assessment of the probable impact of particulate inorganic species on the performance of NOx reduction technologies." Unfortunately, despite the significant amount of sampling and analyses conducted, it does not appear this report did much to address this question. Regarding the July 2009 Microbeam report, we make the following observations:

On page 29, Microbeam summarizes that the PM mass loading at the ESP inlet was 4.96 x 10^6 μg/dscm, the PM mass loading at the scrubber inlet was 1.1 x 10^4 μg/dscm, and the PM mass loading at the scrubber outlet was 1.08 x 10^4 μg/dscm. In regard to this, Microbeam states, "[t]hese results show very little overall removal of the submicron particulate across the wet scrubber system."[48] This statement, presented as if it has great significance, is a red herring. As Microbeam indicates immediately after making this statement, "[a] significant fraction of the particulate was removed by the ESP, with a removal efficiency of 99.76%." Therefore, because the ESP removed almost all of the PM, *there was very little PM left to be removed by the scrubber*. This is a central, highly relevant fact that should have been considered in any TESCR technical feasibility analysis. In other words, regardless of the exact mass of alkali and/or alkaline earth metals in the exhaust stream LDSCR would see much less that HDSCR catalyst. Instead, it has largely been ignored. The scrubber's efficiency in a particular particle size range is a distant secondary issue to the threshold issue of whether there was enough mass of alkali and/or alkaline earth metal particles of any size to cause SCR deactivation—an issue Microbeam does little to illuminate.

Microbeam presents a great deal of information concerning the particle size and frequency distribution of particles at the inlets and outlets of control devices in the pollution control train It also presents information concerning the mass of particles versus their size at these locations. We find this to be of limited use in determining the degree to which SCR catalyst located at any

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[47] Final Report: Assessment of Particulate Characteristics Upstream and Downstream of ESP and Wet FGD, Prepared for: Minnkota Power Cooperative, Inc. Milton R. Young Power Station Center, ND, Prepared by: Microbeam Technologies, Inc., UND Energy and Environmental Research Center, and UND Chemical Engineering, July 1, 2009.

[48] A similar statement appears on page 30: "Downstream of the scrubber the composition size distribution determined for sodium, potassium, calcium and sulfur showed significant levels of sodium and sulfur in size fraction finer than 1 μm."

of those positions would deactivate due to poisoning. Certainly, smaller particles are favored in catalyst chemical poisoning due to the reaction of alkali and alkali earth metals on the catalyst acid sites. However, the central question concerns mass, not particle size. In other words, the real question is what was the total mass of alkali and/or alkaline earth metals at HDSCR, LDSCR, or TESCR configurations. We could not find these mass loadings actually tabulated in the report and only see them represented in bar chart form in Figure 23. Unfortunately, Microbeam does not appear to interpret this information.

In its May 2009 BACT LDSCR and TESCR analyses, North Dakota indicated that the latest PM stack tests at the time for Milton R. Young Unit 2 (8/07 and 5/08) indicated an average PM emission rate of 10.61 mg/Nm^3 at 6% O_2. North Dakota combined this with particulate size distribution data by Markowski[49] and conservatively estimated that the total emission rate for sodium and potassium sulfate combined that would contact a TESCR. North Dakota estimated that particulate loading that is less than or equal to 0.1 micrometers in size was 0.98 mg/Nm^3, of which 0.78 mg/Nm^3 was sodium sulfate. North Dakota then compared this mass loadings to those considered in the Zheng and Kling studies (discussed in our analysis of the May 2009 BACT Report). North Dakota concluded that the catalyst life for a TESCR configuration at the Milton R. Young would be longer than the testing indicated by Zheng and Kling. North Dakota used this information to conclude that both LDSCR and TESCR configurations are technically feasible. Interestingly, although the Microbeam results do not provide much information (with the exception of Figure 23) concerning the mass loading of alkali and/or alkaline earth metals, it does indicate that the total PM loading at the scrubber outlet was measured to be 1.08 X 10^4 µg/dscm. Converting this figure to mg/Nm^3, results in a value of 10.8 mg/Nm^3, which is less than 2% more than the mass loading North Dakota considered. Alternatively, Microbeam, apparently using Figure 23, indicates in its summary that the total quantity of sodium and potassium exiting the scrubber was between 2,000 – 3,000 µg/dscm, or 20 to 30 mg/Nm^3. Microbeam does not indicate how much of this is within the 0.1 micrometer size fraction that North Dakota considered in its comparison to the Zheng and Kling studies. However, even we were to consider all of the 20 to 30 mg/Nm^3 to be within that 0.1 micrometer size range, it would still place it within the range North Dakota considered. Therefore, it appears to us that when salient data is extracted from the Microbeam report, it reinforces North Dakota's determination that LDSCR and TESCR configurations are technically feasible.

Our Conclusions Regarding the July 2009 Microbeam Report

Much of Microbeam's report did not directly consider the two fundamental questions. However, what little salient data Microbeam reported appears to reinforce North Dakota's determination that LDSCR and TESCR configurations are technically feasible.

[49] North Dakota indicates the Markowski data was part of February 20, 2009 submission entitled, "Supplemental Information for Consideration Regarding NOx BACT for M.R. Young Station Units 1 and 2: Technical Feasibility Issues for TESCR and LDSCR Retrofit." We have not reviewed the Markowski information and accept it at face value.

3.7 Review of SCR Catalyst Vendor Correspondence

In this section, we review all of the SCR catalyst vendor correspondence from all parties, to the extent that information is in the record. This information spans a wide time frame from 2007 to 2010 and is therefore out of sync with documents we have already covered and have yet to cover. However, because North Dakota and the United States District Court for the District of North Dakota have placed a significant amount of weight on the interpretation of that correspondence, we believe it is important to present our review of that information before reviewing North Dakota's final NOx BACT determination for the Milton R. Young facility, and the Court's review of EPA's challenge to that determination.

Much of the record regarding catalyst vendor correspondence is focused on CERAM and Haldor Topsoe. In fact, both North Dakota and the United States District Court for the District of North Dakota, [50] only cited to Minnkota's CERAM and Haldor Topsoe correspondence as reasons for finding that SCR in any configuration is infeasible. However, although Mr. Hartenstein's correspondence included those two vendors, it was in fact much wider.

In several places in the record, allegations are made that Mr. Hartenstein was less than open and straightforward about the information he passed to the vendors and SCR equipment manufacturers. For instance, in its Nov 2010 North Dakota BACT Finding of Fact, North Dakota states:[51]

> The Department of Justice, through its contractor Evonik Energy Services, LLL (Evonik) provided a Request for Proposals (RFP) to HTI and CERAM supposedly based on the flue gas characteristics of MRYS. Both companies indicated they would provide catalyst life guarantees to Evonik based on the RFP. HTI and CERAM have provided letters explaining this seeming contradiction. Both have indicated that Evonik did not provide a fuel analysis, ash analyses, the range of fuel and ash characteristics that could be encountered, details on the soluble constituents in the flue gas and the fact that it was North Dakota lignite. HTI believed the RFP was for a facility burning eastern subbituminous coal. HTI indicated they would not have provided a guarantee if it had known that the fuel was North Dakota lignite. CERAM has indicated it would not have provided a guarantee if the Evonik RFP had provided the same level of detail as the Minnkota RFP. The RFP by Evonik and subsequent proposals by CERAM and HTI proved nothing and have no value.

It appears that North Dakota's revised view of the catalyst vendors' correspondence came after Minnkota submitted its own RFP to CERAM and Haldor Topsoe and stems from hand written

[50] Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365.
[51] Nov 2010 North Dakota BACT Finding of Fact. See page 9.

notes to apparent phone conversations with CERAM and Haldor Topsoe, North Dakota indicated the following responses to questions concerning this:[52]

> Question to CERAM: You indicated a willingness to provide a guarantee to DOJ's contractor (Hartenstein), clarify the difference between Minnkota's and Hartenstein's proposals.
>
> Notes from Person 1 on CERAM's response: "Not enough info, level of detail, range of fuel not included, sodium ion (double in B&McD)."
>
> Notes from Person 2 on CERAM's response: "It wasn't stated that it was the same, however it was very different because sodium from Minnkota was double what Hartenstein provided."
>
> Notes from Person 3 on CERAM's response: "Thought looked sim. to Minn. But sign. dif. in info. Most glaring was sodium (almost double in B&M request.)"
>
> Question to Haldor Topsoe: You indicated a willingness to provide a guarantee to DOJ's contractor (Hartenstein), clarify the difference between Minnkota's and Hartenstein's proposals.
>
> Notes from Person 3 on Haldor Topsoe's response: "Hans – deception to Haldor, minimal info, no ash info."
>
> Notes from Person 4 on Haldor Topsoe's response: It was obvious it was sent as a deception to H. Topsoe. Assumed it was Eastern Bituminous Coal. No ash information. Minimal amount of information.

Thus it would appear from the above notes that Mr. Hartenstein's RFP to CERAM and Haldor Topsoe (1) lacked sufficient detail concerning the exhaust gas chemistry of Milton R. Young, (2) included half the sodium content in comparison to the submitted by B&McD, and (3) was considered a deception by Haldor Topsoe.

The Court accepted North Dakota's characterization of Mr. Hartenstein's RFP when it stated, "In the spring of 2010, it became clear to North Dakota that the EPA's solicitation omitted key information about the units under consideration. When the vendors were presented with actual information about the units for which they had offered a "guarantee," they abruptly withdrew the guarantees."[53] This "evidence" featured prominently in the Court's decision making.

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[52] See the file, https://www.regulations.gov/contentStreamer?documentId=EPA-R08-OAR-2010-0406-0314&attachmentNumber=12&contentType=pdf, which appears to be hand written notes concerning call records between North Dakota and CERAM. Notes appear to have been made from four different people, some of who did not attend both calls. No date appears for the CERAM call but the Haldor Topsoe call was dated either 7/15/2010 or 9/15/2010.

[53] Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365. See pages 31-32.

However, as we demonstrate, none of Mr. Hartenstein's correspondence with vendors was deceptive. In his June 2008 correspondence, Mr. Hartenstein made it perfectly clear to the catalyst and the SCR equipment vendors he contacted that he was discussing the Milton R. Young Facility. In fact, some of these vendors acknowledged their familiarity with the facility, which is to be expected *since these were the same vendors that had previously been contacted by Minnkota as we describe in our coverage of the April 2007 B&McD Catalyst Vendor Correspondence*.[54] Later in his February 2010 RFP, Mr. Hartenstein provided more than adequate information, and accurate and appropriate information to catalyst vendors.

3.7.1 April 2007 B&McD Catalyst Vendor Correspondence

In May of 2008, B&McD issued a report in which it interpreted replies from various catalyst vendors and SCR equipment vendors it solicited during April, 2007.[55] B&McD's inquiries were limited to HDSCR configurations. They were sent to eight vendors, of which six replied. It is important to note that B&McD provided detailed information concerning the Milton R. Young facility. Because Mr. Hartenstein's subsequent inquiries were to the same vendors, specifically about the same facility, these vendors were in no way ignorant of the information they needed in order to reply to Mr. Hartenstein. As B&McD's queries only concerned HDSCR, we only summarize them here.[56]

Three vendors (Alstom, CERAM, and Haldor Topsoe) acknowledged the challenges, suggested that additional testing would be required, but ultimately concluded that HDSCR could be implemented at Milton R. Young. In particular, CERAM was quite adamant about its position. Babcock and Wilcox declined to offer an opinion. Babcock Power also declined to offer an opinion and suggested that an engineering study be performed. Several vendors mentioned the difficulty presented with the exhaust gas temperature fluctuation that would be experienced by a HDSCR configuration at Milton R. Young. Alstom indicated that this could be solved via modification or replacement of the economizer. It is important to understand that these vendor responses concerned only a HDSCR configuration. As all parties have acknowledged, this configuration, being subject to a completely uncontrolled particulate environment, would experience the greatest degree of catalyst deactivation. *Even so, three vendors concluded that the HDSCR configuration could be implemented.* The fact that these vendors also suggested that additional testing would be required doesn't change their conclusions but rather it qualifies their guarantees. As we indicate with Mr. Hartenstein's correspondence with these same vendors (and others) reaffirmed this position.

3.7.2 June 2008 Hartenstein Catalyst Vendor Correspondence

In the July 2008 Hartenstein Report, Mr. Hartenstein states that he contacted the same vendors that participated in the April 2007 B&McD query. Unlike the April 2007 B&McD Catalyst Vendor Correspondence, these vendors were also queried about the feasibility of a TESCR

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[54] July 2008 Hartenstein Report. See pages A-57 to A-66.

[55] May 2008 Minnkota Vendor Responses. Extracted from: Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Responses to NDDH and EPA Comments Regarding SCR Technical Feasibility and Non-SCR Concerns Milton R. Young Station Unit 1 and Unit 2 NOx BACT Analysis Study, April 18, 2007.

[56] See Appendix A to the May 2008 Minnkota Vendor Responses.

configuration. He summarizes his correspondence with catalyst vendors and SCR equipment vendors as follows:[57]

> As a matter of fact a quick vendor survey conducted by me confirmed that all contacted vendors consider TESCR as being unquestionably technically feasible, available and applicable for M.R. Young Station. This was not only unanimously confirmed by all leading catalyst manufacturers (Argillon, CERAM, Cormetech, Haldor Topsoe and Hitachi) but also by leading SCR equipment vendors (Alstom, Babcock Power and Babcock & Wilcox[58]). Furthermore, these SCR equipment vendors and catalyst manufacturers confirmed my opinion by stating that they also consider LDSCR as technically feasible and probably even HDSCR, however not without significant but resolvable technical challenges such as limiting the boiler outlet temperature variations to a range tolerable for SCR catalyst and eliminating the popcorn ash problem. The temperature variations at the boiler outlets appear to be the biggest hurdle for the application of HDSCR at this time; however, this issue is considered to be technically resolvable as indicated by Babcock & Wilcox, who supplied both boilers at M.R. Young Station. Answering the question of whether or not the extent of modifications of existing equipment required to resolve the temperature variation issue makes HDSCR economically less attractive in comparison to LDSCR or even TESCR is beyond the scope of this report. |

It is important to note that these emails were follow-ups to phone conversations Mr. Hartenstein had with the persons involved[59] and all vendors knew the SCR installation would be at the Milton R. Young facility and that that facility burned North Dakota lignite. All vendors were asked the following questions:

Given your knowledge about the plant (cyclone-fired B&W boilers, ESP, wet scrubber) and the fuel (North Dakota lignite), would your company:

> a. Consider a tail-end SCR technically feasible?
>
> b. Recommend or require additional pilot testing?
>
> c. Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?

In its June 19, 2008 email, Babcock Power stated:

> Babcock Power has reviewed the Milton Young plant in the past, based on these reviews Babcock Power finds [a] TESCR is technically and commercially

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[57] July 2008 Hartenstein Report. See page A-5.

[58] Note that Babcock Power has historical ties to Babcock and Wilcox, but is a separate company.

[59] As Mr. Hartenstein indicates in his emails, all the vendors contacted also considered a HDSCR configuration "principally technically, feasible even though not without technically resolvable challenges for Minnkota's Milton R. Young Station."

> feasible. Babcock Power does not recommend or require additional pilot testing only proper flue gas characterization as with any SCR system per performed. Will provide commercial guarantees for the SCR and catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime. Babcock Power has the largest SCR experience list in the world, from this experience we are completely confident in the application of a tail end system at Milton Young.

Thus, the engineering company which claimed to be the most experienced SCR installer in the world, *who was familiar with the Milton R. Young facility*, had enough information to conclude that it was completely and unequivocally confident that a TESCR configuration would be viable without additional testing. It is difficult to imagine how this statement could be more clear.

In its June 23, 2008 reply, Babcock and Wilcox replied (in italics):

- Consider a tail-end SCR technically feasible? *Yes*.

- Recommend or require additional pilot testing? *Requires further discussion with catalyst suppliers.*

- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be? *While B&W has considered tail-end SCR systems on other projects we have not had these commercial guarantee discussions with the catalyst suppliers for the North Dakota lignite application. Before consideration of providing these guarantees a comfort level would be required after obtaining guarantees from catalyst suppliers.*

Again, another very experienced SCR installer considered TESCR technically feasible. The fact that it wanted to further discuss pilot testing and guarantees with catalyst vendors was not a condition or qualifier to its determination that a TESCR configuration at Milton R. Young was feasible. As other vendors have acknowledged (noted below), this is merely a consideration to properly designing the type and size of the catalyst—not whether a TESCR configuration is feasible.

In its June 24, 2008 reply, Argillon, a catalyst vendor, which claimed more TESCR experience than any other catalyst manufacturer, replied:

> Consider a tail-end SCR technically feasible?
>
> Yes, we consider this configuration to be technically feasible. As you know, tail end SCRs are often used when there are significant catalyst poisons in a flue gas stream. A wet scrubber can remove most of these poisons, resulting in very low catalyst deactivation.
>
> Recommend or require additional pilot testing?

> For a high dust configuration, we would say definitely. For a tail-end configuration, we would say no. We would only like to see a flue gas analysis for conditions at the inlet to the SCR in order to predict deactivation rate.
>
> Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be?
>
> Generally speaking, yes, we would provide guarantees for DeNOx & slip as specified (not to exceed 90% or 2 ppm), 24k hours life, SO_2 conversion rate - low but value TBD, pressure drop - value TBD. Of course we would have to see the technical specifications before being more specific. In addition, tail-end SCRs perform much longer, so depending on the application specifics, customer, etc., we may decide to extend the operating life guarantees. This is a commercial decision and will be reviewed on a case-by case basis.

Therefore, the catalyst manufacturer who claimed the most experience in TESCR in the world, completely and unequivocally stated that a TESCR configuration at Milton R. Young was technically feasible and would not require pilot testing. Additional information would only be required to be specific about guarantees concerning the catalyst life, SO_2 to SO_3 conversion rate, and pressure drop.

In its June 25, 2008 reply, CERAM, a catalyst vendor, with extensive experience replied:

> CERAM certainly considers the use of a tail-end SCR on applications such as the Milton R. Young Station as technically feasible provided a proper design approach is used. CERAM has the experience from more than 100 tail-end and low dust applications dating from 1988 that would substantiate our opinion. For a tail-end approach we see no need for additional pilot testing. As such, we can provide full commercial guarantees for catalyst performance (activity or lifetime, conversion rate, pressure drop, etc.).
>
> The choice between high dust and tail-end processes certainly should consider capital costs, operating costs and process risk. Based on our experience certainly process risk would favor a tailend approach, but albeit for most circumstances at a higher "all-in" cost. Should very high retrofit factors be present for a high dust arrangement then the relative economic factors may even favor a tail-end approach.

Again, another experienced catalyst vendor considered a TESCR configuration at Milton R. Young as technically feasible without further pilot testing. As we noted above, CERAM is one of the catalyst vendors claimed by North Dakota, Minnkota, its consultants, and the Court to have changed its mind once if had more detailed information. In our discussion of what correspondence from CERAM is available, we will demonstrate why this interpretation is a mischaracterization.

In its June 19, 2008 replies (in italics), CORMETECH, a catalyst vendor, again with extensive experience replied (in italics):

- Consider a tail-end SCR technically feasible? - *yes*

- Recommend or require additional pilot testing? - *We generally do not consider coupon testing an accurate representation of an SCR, however in order to minimize cost and provide basic screening information we would suggest the potential use of a coupon sample test. If the coupon shows significant accumulation of catalyst poisons, a subsequent slipstream type test which is more representative of a full scale SCR i.e., match velocity, AVs, etc. would be recommended.*

- Be willing to provide commercial guarantees for catalyst performance (activity, pressure drop and SO_2/SO_3 conversion rate) and lifetime? If so what would these be? *Presuming the coupon test does not show anything unusual (which we do not expect to see anything unusual) we would be willing to provide commercial guarantees for a low dust application. Basic guarantees would be associated with life (this would not include specific Ko and K/Ko as guarantees - the guarantee would be an efficiency and slip guarantee at a certain number of operating hours), SO_2 conversion, pressure loss.*

In a second email that day, CORMETECH clarified its statements on coupon testing:

> I was thinking of if you put a coupon in the tailend location and it showed something weird then you would have to do something more elaborate i.e. a slipstream with longer hours, etc. We do not anticipate this - in fact you could probably do without the coupon test as well since l don't see any reason why this system would be any different the primary tail end experience i.e. Unlikely any nasties make it through the lower temperature environment and scrubber process. The coupon is OK but l really don't expect to see much. Finally, we have not done any specific coupon tests (because slipstream has been the primary way to evaluate) so we would need to think through the best way to do it - i.e. holder, mounting arrangement, test method, hours of exposure, etc. If you already have something in mind please let us know.

CORMETECH states that it considers TESCR at Milton R. Young to be technically feasible. Also, although CORMETECH's replies appear to be less clear than the other vendors, it does not expect a TESCR installation at Milton R. Young to be any different that its existing experience, does not expect that catalyst poisons ("nasties") would be a problem, and it seemed to think that even coupon testing was optional.

In its June 24, 2008 reply, Haldor Topsoe, a catalyst vendor, replied:

> Like you describe we have had very good operating experience with SCR in the clean environment after a scrubber or bag filter. There appears to be practically no catalyst deactivation and with the low amount of particulate the catalyst pitch

> can be small, which both leads to a compact SCR as compared to a high dust SCR.
>
> Based on the clean flue gas after the FGD we would not require any further testing in order to guarantee a catalyst performance.
>
> The actual guarantees would be as normally applied in a high dust installation and depend on the catalyst volume and operating conditions. At the low operating temperature expected at the tail-end position the $02 oxidation will be negligible. [we interpret this to mean that the SO_2 to SO_3 oxidation would be negligible].

On June 24, 2008 Mr. Hartenstein requested clarification:

> Just to make sure that I understand you correctly. Is it correct to state that Haldor Topsoe feels fully confident that a tail-end SCR is technically feasible and would not experience any accelerated catalyst deactivation? Therefore, you would be willing to guarantee catalyst performance (NOx removal efficiency, pressure drop, SO_2/SO_3 conversion rate and catalyst lifetime) without any need for further pilot testing,

On June 27, 2008 Haldor Topsoe confirmed Mr. Hartenstein's statement:

> Your understanding is what I meant to say.

Again, another experienced catalyst vendor considered a TESCR configuration at Milton R. Young as technically feasible without further pilot testing. As we noted above, Haldor Topsoe is one of the catalyst vendors claimed by North Dakota, Minnkota and its consultants, and the Court to have changed its mind once if had more detailed information. In our discussion of what correspondence from Haldor Topsoe is available, we will demonstrate why this interpretation is a mischaracterization.

In summary, all the catalyst and the SCR equipment vendors Mr. Hartenstein contacted were aware that he was discussing the Milton R. Young Facility. These vendors were familiar with the Milton R. Young facility because they had previously been contacted by Minnkota. All the vendors, which collectively have dominant positions in the industry unequivocally considered TESCR technically feasible at Milton R. Young. One SCR equipment vendor (Babcock and Wilcox) wanted to discuss the situation with catalyst vendors before considering further testing and guarantees. One catalyst vendors cited to optional coupon testing. It is apparent that these worldwide leaders in SCR manufacturing and installation were willing to endorse TESCR due to their broad experience in successful applications.

3.7.3 North Dakota Catalyst Vendor Correspondence

In its July 2009 North Dakota SCR BART Report, North Dakota states that it also contacted catalyst and SCR equipment vendors:[60]

> The Department contacted three of the vendors, Ceram Environmental, Haldor Topsoe and Babcock Power. The companies generally confirmed the information in the emails to Mr. Hartenstein. Babcock Power indicated they had no worries about getting 10,000 hours of catalyst life at the M.R. Young Station. However, they recommended "coupon" testing prior to design of the SCR. Ceram was convinced it was technically feasible; however, their representative did acknowledge that if the sodium and potassium aerosols are making it through the ESP and wet scrubber, catalyst deactivation could be a problem. Haldor Topsoe indicated that the catalyst deactivation at M.R. Young would be manageable if the catalyst is kept dry during outages. Although no written guarantees have been provided by the vendors, it appears that vendors are willing to provide them for a tail end SCR at the M.R. Young Station.
>
> Vendors believe that tail end SCR is technically feasible and can be successfully applied at M.R. Young Station.

No additional information concerning these inquiries by North Dakota is provided, so we cannot cite to specific dates or details. Regardless, the record clearly indicates that North Dakota checked Mr. Hartenstein's June 2008 vendor correspondence and found SCR equipment and catalyst vendors opinions that TESCR is technically feasible at Milton R. Young to be accurately represented.

3.7.4 January 2010 Catalyst Vendor Letters

On January 6, 2010, B&McD sent identical letters to CERAM and Haldor Topsoe, two catalyst vendors, requesting confirmation of the accuracy of the following statements:[61]

> During preparation of the cost estimate, Burns & McDonnell consulted with two SCR catalyst vendors experienced with biomass-fired boiler SCRs and European coal-fired boilers with low-dust and tail end SCR systems. However, neither of these vendors was willing to guarantee a catalyst replacement schedule for cyclone boilers firing North Dakota lignite without results following successful extensive pilot-scale slipstream testing that confirm the deactivation and fouling rates. According to these catalyst suppliers, there is no SCR operating experience in the world found to be directly comparable to the hypothetically applied tail end and low-dust SCR cases on North Dakota lignite-fired cyclone boilers being evaluated. Thus they were unable to offer a guaranteed catalyst replacement schedule based on their experience.

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[60] July 2009 North Dakota SCR BART Report. The first statement appears on page 23. The second statement appears on page 24.

[61] April 2010 North Dakota Prelim BACT Determination, Appendix B.

Both catalyst vendors replied in the affirmative. There does not appear to be any direct information in the record to explain the apparent change in position these vendors took in comparison to that expressed in email correspondence with Hans Hartenstein in June 2008.[62] We note that in its January 11, 2010 letter to Minnkota, North Dakota requested a number of items, one of which is all correspondence with SCR catalyst vendors.[63] In its February 11, 2010 reply to North Dakota's inquiry, Minnkota states that the non-confidential material was supplied in Enclosure C and that the confidential information was supplied in Enclosure D on CDs.[64] We do not have access to that CD, and it appears that despite Minnkota's stating that it was non-confidential, it was nevertheless treated as confidential.[65] However, as we indicate in the next section, it appears some clarification from the catalyst vendors was obtained.

3.7.5 February 2010 Hartenstein Catalyst Vendor Request for Proposal [66]

In February 2010, Mr. Hartenstein sent an RFP[67] to a number of catalyst vendors for LDSCR and TESCR bids. As EPA indicates:[68]

> Due to the inflated nature of B&McD's cost estimates, EPA conducted an independent cost analysis for LDSCR and TESCR at MRYS. This analysis consisted of two parts. The first was to request budgetary proposals from several catalyst vendors on catalyst performance guarantees (NOx removal, initial catalyst life, and ammonia slip), catalyst volume and dimensions, catalyst exchange diagrams up to approximately 100,000 hours, and catalyst price. The Request for Proposal (RFP) was based on what EPA believes to be representative flue gas characteristics and design specifications for a LDSCR on Unit 1 and a TESCR on Unit 2.
>
> The RFP was sent to three catalyst vendors (CERAM, Johnson Matthey Catalysts (JMC), and Haldor Topsoe) on March 3, 2010. While the facility in the RFP was not identified as MRYS, the flue gas characteristics in the RFP were based on

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[62] *Ibid.* See Appendix B: SCR Vendor Query Correspondence, July 2008 Hartenstein Report.

[63] *Ibid.* This is included as Appendix B: January 11, 2010 Letter from Terry O'Clair, Director, Division of Air Quality, NDDH to John Graves, Environmental Manager, Minnkota Power Cooperative, Inc. Subject SCR Cost Estimates.

[64] *Ibid.* Appendix B February 11, 2010 Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative Followup Responses to Presentation and NDDH Request for Additional Information Supplemental NOx BACT Analysis Study M R Young. See page 10.

[65] For instance, the docket for EPA's September 21, 2011 proposal on North Dakota indicates that Appendix B; Enclosure C; Non-Confidential Vendor Correspondence (2-11-10) "is restricted to show metadata only because it contains confidential business information data." See https://www.regulations.gov/document?D=EPA-R08-OAR-2010-0406-0052.

[66] There are referenced to an April 2010 report by Mr. Hartenstein. However, we did not review it since it is likely designated as CBI. See, for example, this report referenced in North Dakota's 7/28/11 SIP amendment: "Report of Hans Hartenstein: On North Dakota Department of Health's April 10, 2010 BACT Determination for Minnkota's MR. Young Station, Expert Report of Hans Hartenstein, On Behalf Of The United States Department Of Justice", dated April 2010." It is also referenced by EPA in its 5/10/10 comments on North Dakota's April 2010 BACT report. AR 249 in the docket states that it is CBI.

[67] February 2010 Hartenstein SCR RFP.

[68] May 2010 EPA Comments on North Dakota April BACT. See page 23.

> relevant actual flue gas parameters found at MRYS, including recent stack test information for Unit 1 and Unit 2 and the 1983 Markowski data on particulate matter concentrations and compositions data for Unit 2. Furthermore, it was clearly stated in the RFP that the majority of the sulfates within the particulate matter are expected to be sodium and potassium sulfates. Upon request from two catalyst vendors (CERAM and JMC), a typical coal composition of Center lignite was provided. Responses from all three vendors were received between March 12 and March 31, 2010. As noted in Mr. Hartenstein's expert report, all three catalyst vendors were able to provide an initial catalyst life guarantee of 24,000 operating hours in response to the RFP, as well as providing catalyst size and price specifications at the guaranteed NOx and ammonia slip rates. More detail is provided in Mr. Hartenstein's expert report.

Minnkota was critical of Mr. Hartenstein's RFP.[69] Below, we focus on those comments pertaining to the technical feasibility of SCR at Milton R. Young.[70]

In several places, Minnkota states that Mr. Hartenstein's RFP did not contain the level of detail its own 2009 RFP included.[71] However, these assertions either (1) conflate the information necessary to determine technical feasibility with cost analysis, or (2) are irrelevant to the question of technical feasibility and/or the level of cost analysis required. For instance, Minnkota states: "The previous effort involving Minnkota provided a design basis to the catalyst vendors including a very detailed characterization of the coal and ash composition, along with particulate components in the flue gas stream with actual aerosol data for the flue gas desulfurization system absorbers' inlets and outlets, and at the inlet to Unit 2's electrostatic precipitator, based on values measured in 2009."[72] However, as we note in our review of the July 2009 Microbeam Report, little information was actually presented concerning the mass loading of alkali and/or alkaline earth metals, and thus did little to address the two fundamental questions regarding North Dakota lignite SCR technical feasibility: (1) What is the mass loading of alkali and/or alkaline earth metals a LDSCR and a TESCR would experience at North Dakota lignite fueled EGU, and (2) What effect would these mass loadings have on catalyst life? Revealing this information was assiduously avoided by Minnkota and its consultants, despite the many studies and sampling they performed.

Minnkota also states, "These two vendors [CERAM and Haldor Topsoe] were not instructed to consider the very detailed site-specific boiler information, the actual coal and ash analyses, or the 2009 flue gas aerosol data (all of which are part of the public record on the NDDH's website) for characterizing the fuel and flue gas composition upstream of the Unit 2's electrostatic precipitator, flue gas desulfurization system absorber inlet and outlet provided previously by

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[69] July 2010 Minnkota Comments to North Dakota. See pages 17 – 22.

[70] Thus, comments concerning cost or whether particular equipment unrelated to basic technical feasibility (number or reactors, layers of catalyst, specific reheating mechanism, ammonia or urea, etc.) should or should not have been specified are ignored.

[71] We were not able to find any documents associated with Minnkota's 2009 RFP to CERAM and Haldor Topsoe, beyond those discussed herein. We conclude they were claimed as confidential business information and are therefore not available.

[72] July 2010 Minnkota Comments to North Dakota. See page 17.

Minnkota and their consultants." Again, none of this information, *beyond what was supplied in Mr. Hartenstein's RFP*, actually relates to the technical feasibility of SCR.

First, although some of this information may be needed in order to provide a Firm, Contractor, or Detailed cost estimate (+/- 5%), it is unnecessary in order to perform a study-level estimate to +/- 30%, required by BACT and BART cost analyses.[73] In fact, Sargent and Lundy, one of the consultants retained by Minnkota for various services, including cost analyses, itself provides a SCR cost methodology to EPA which is used for BART analyses.[74] This cost model, only requires unit size, retrofit factor, heat rate, NOx rate, SO_2 rate, type of coal, NOx removal efficiency, urea cost (50% wt solution), catalyst cost, aux power cost, steam cost, and operating labor rate.[75] Although this is a hot side, HDSCR cost model, the point is the same — relatively limited information is necessary in order to prepare a study-level SCR cost analysis. Thus, much of Minnkota objections concerning a lack of supplied data is irrelevant to the type of cost analysis required. As we will discuss below, these objections are also irrelevant to the question of technical feasibility.

Second, although the focus of this report is not cost, the information provided by Mr. Hartenstein in his February 2010 RFP greatly exceeded the level of detail necessary for a study-level cost analysis, and was adequate to characterize the exhaust gas stream to the extent necessary for vendors to determine if they could provide catalyst guarantees. Again, the key information necessary for vendors to determine whether they could offer life catalyst guarantees was the particulate mass loading, especially of alkali and/or alkaline earth metals. Mr. Hartenstein provided the total particulate mass concentrations downstream of the ESP and the scrubber—at the LDSCR and TESCR locations, respectively. He also clearly stated that "The majority of the sulfates must be expected to be sodium and potassium sulfates."[76] Consequently, catalyst vendors could have assumed a worst-case analysis that all of the particulate mass was due to alkali and/or alkaline earth metals. This is the key information catalyst vendors needed in order to assess the degree of catalyst deactivation. In addition, Mr. Hartenstein's RFP also contained particulate size fractionation downstream of the ESP and the scrubber—information frequently cited by Minnkota and its consultants as being important to properly characterizing the exhaust gas stream. Vendors had complete freedom to request any additional information they deemed necessary, and in fact two did so. As EPA indicates, "Upon request from two catalyst vendors (CERAM and JMC), a typical coal composition of Center lignite was provided."[77] It is difficult to imagine that catalyst vendors would have provided catalyst guarantees without having concluded they had the necessary information.

As we indicate at the beginning of this section, it has been alleged by North Dakota and Minnkota that Mr. Hartenstein withheld important information or otherwise attempted to deceive

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[73] See EPA's Control Cost Manual, Section 1, Chapter 2, November 2017. See page 6.

[74] See https://www.epa.gov/airmarkets/ipm-v6-emission-control-technologies-attachment-5-3-scr-cost-development-methodology. Note that Control Cost Manual Section 4, Chapter 2 references this cost methodology on pdf page 53.

[75] Note that although the type of coal is an input, this information is not used to consider the chemistry of the exhaust gas stream, but rather is used in Sargent and Lundy's least-squares curve fitting of existing SCR cost examples.

[76] February 2010 Hartenstein SCR RFP. See page 6 of 11.

[77] May 2010 EPA Comments on North Dakota April BACT. See page 23.

the catalyst vendors with his February 2010 RFP. Even a cursory analysis of this situation shows this to be untrue. Again, the catalyst vendors had complete freedom to request any information they deemed necessary in order to complete their proposals. Two requested and were supplied with additional information concerning the lignite burned by Minnkota from the Center Mine. Whether the fuel was coal or lignite, eastern or western, is immaterial. The only compositional information pertinent to catalyst deactivation was provided—the particulate mass loading which the vendors were instructed to regard as being a majority of potassium and sodium sulfates. The only possible issue could have been if either particulate mass loading and/or Center Mine compositional analysis was in error. In fact, North Dakota and Minnkota alleged just that.

In a June 11, 2010 letter addressed to CERAM, CERAM explained why it agreed to provide Evonik (Mr. Hartenstein's company) with both initial and end of life catalyst guarantees in response to Mr. Hartenstein's February 2010 RFP, while only providing Minnkota an initial catalyst guarantee in response to its 2009 RFP:[78]

> The range of fuel analysis provided by Evonik was not as detailed as that provided by Minnkota, and considered a lower maximum range of key constituents that can contribute to catalyst poisoning. For example the Evonik specification listed the maximum sodium content to be significantly less than the Minnkota specification. Sodium is a significant catalyst poison that must be considered for the purpose of guarantees. CERAM must consider the full range of potential coals when supplying catalyst performance guarantees.
>
> Minnkota submitted with the RFP the entire study performed by Microbeam Technologies, Inc. (MTI) titled *Assessment of Particulate Characteristics Upstream and Downstream of ESP and Wet FGD.* This study included detailed flue gas characterization including details on particle size distribution, particle concentrations, and soluble sodium constituents in the flue gas.
>
> Minnkota submitted with the RFP the final report titled *Impact of Lignite Properties on Powerspan's NOx Oxidation System.* The report outlined the impacts of the North Dakota Lignite flue gas and fly ash on Powerspan's multi-pollutant control system called electrocatalytic oxidation (ECO) technology, specifically the sodium-rich aerosols and small ash particles which accumulated and became bonded of the surface of the silica electrodes used in this technology.

Regarding the allegation that Mr. Hartenstein's RFP understated the amount of sodium, we note that Mr. Hartenstein's RFP directly employed the relevant data from the July 2009 Microbeam Report. This included the same charts depicting the total particulate loadings and particulate size distribution at the inlet and outlet of the scrubber for Unit B (Unit 2 of Milton R. Young) and the particle size distribution for total particulates and sulfate particulates. Therefore, when Mr. Hartenstein provided the Microbeam sulfate particulate concentrations in $\mu g/m^3$ and instructed the vendors that "The majority of the sulfates must be expected to be sodium and potassium

[78] See the CERAM letter dated June 11, 2010 and similar Haldor Topsoe letter dated July 27, 2010 which are attached to the end of the July 2010 Minnkota Comments to North Dakota.

sulfates,"[79] he was using Microbeam's own data and conservatively estimating the mass loading of sodium and potassium.

In its July 2010 Minnkota Comments to North Dakota, Minnkota alleges that Mr. Hartenstein's February 2010 RFP was inaccurate and differed in key areas from those it provided to catalyst vendors in 2009. For instance, Minnkota states:[80]

> Mr. Hartenstein incorrectly assumes that actual measured particulate mass rates from stack tests should be used as the basis in preliminary LOSCR and TESCR process designs. The preliminary design approach taken by Burns & McDonnell for Minnkota's hypothetical applications of LDSCR and TESCR technologies for MRYS was to assume the permissible limit for particulate mass per unit of heat input emissions from the ESPs (0.03 lb/mmBtu) as required in Minnkota's April 2006 Consent Decree for MRYS Unit 1 and Unit 2 with wet FGD systems. Electrostatic precipitator hourly average outlet mass particulate outlet emissions were assumed as 0.03 lb/mmBtu x 2,955 mmBtu/hr = 88.7 lb/hr for Unit 1 and 0.03 lb/mmBtu x 5,158 mmBtu/hr = 155 lb/hr for Unit 2.

Here, Minnkota states that it didn't use the Microbeam report's figures for particulate mass rates, instead basing those figures on its permit limits. Minnkota's attempt to tie this decision to its consent decree is in our opinion disingenuous: nowhere in its consent decree is it stipulated that Minnkota must base a future SCR design on its maximum permitted particulate limit. The consent decree merely specifies the particulate limit.[81] Also, EPA and states have consistently utilized actual emissions in conducting control cost analyses—not the maximum permitted values. This was required in the BART Guidelines,[82] and is the method used in the Control Cost Manual, for instance in selecting a SCR NOx inlet selection. [83] Numerous examples are available of EPA and states basing the inlet emissions to various retrofit control cost analyses on the historically measured values of those emissions.

Therefore, it appears that in its own RFP, Minnkota and its consultants assumed a higher particulate mass loading than was actually measured by its own consultant, Microbeam. When Mr. Hartenstein correctly used the actual Microbeam particulate mass loadings (total and sulfate particulates), instructing the catalyst vendors to assume the majority of sulfate particulates existed as sodium and potassium sulfates, he was wrongly criticized of underestimating those values. Therefore, the statements in the handwritten notes by North Dakota regarding its conversations with CERAM and Haldor Topsoe, that we reproduced earlier, wrongly imply that Mr. Hartenstein's RFP was incorrect or misleading. In fact, Minnkota's RFP contained inflated

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[79] February 2010 Hartenstein SCR RFP. See pages 5 and 6 of 11.

[80] July 2010 Minnkota Comments to North Dakota. See page 33. Note that many of Minnkota's objections to figures/assumptions in the February 2010 Hartenstein SCR RFP concern control cost issues (as opposed to technical feasibility issues) and are not covered herein.

[81] April 24, 2006 Consent Decree. See page 25.

[82] See 70 FR 39167: "In general, for the existing sources subject to BART, you will estimate the anticipated annual emissions based upon actual emissions from a baseline period."

[83] EPA Control Cost Manual. Section 4, Chapter 2 Selective Catalytic Reduction. See pdf page 56: "The inlet NOx emissions level, [is] obtained from analyzing the boiler flue gas stream," [not based on assuming maximum permitted levels].

particulate mass loadings which these vendors assumed were correct. Similarly, when the Court accepted North Dakota's findings, it assumed the same incorrect conclusion and incorporated that flawed information into its decision making.

3.7.6 March 2010 Haldor Topsoe and CERAM Statements

Via email exchanges with North Dakota's Tom Bachman on March 24, 2010, Haldor Topsoe agreed to release limited statements concerning its SCR proposal for Milton R Young.[84] These statements are reproduced below and appear to be partly redacted:

> HTI believes that the low dust (after ESP) option is the most viable. HTI feels that deactivation of the catalyst due to alkali poisoning (sodium) will be the biggest challenge. However, with that said, HTI also recognizes that chemical deactivation can generally be managed with the adjustment of catalyst volume and/or guarantee life while the potential exists that physical deactivation due to catalyst blinding and plugging could be severe enough to make SCR a non-viable option for controlling NOx emissions.
>
> The absence of SO_2 downstream of the FGD has been discussed and the effect it might have on physical deactivation of the catalyst due to blinding. Considering that most of the calcium will be removed in the ESP, calcium sulfate formation should be minimal. Also, considering the low operating temperature of the SCR (~600F) chemical poisoning of the catalyst affects the observed activity much more than does physical poisoning (blinding) of the catalyst. The tail-end option should be considered further with actual slip stream or mini reactor testing on an operating unit but at this time HTI feels that with the data currently available that the low dust option is the best option available.
>
> HTI's main concern in relation to the lignite fuel is the content of alkali metals (sodium in the case of NO lignite) which leads to chemical poisoning of the catalyst by reacting with the vanadium active sites. The deactivating effect of sodium (and potassium) will be the same, whether in the form of oxide, sulfate or another salt. The deposition rate of the aerosols could be different, though, depending on whether they are in the form of oxides or sulfates due to differences in mobility.

Via email exchanges with Minnkota's John Graves to North Dakota's Tom Bachman on March 17, 2010, CERAM similarly agreed to release limited statements concerning SCR proposal for Milton R Young. These statements are reproduced below and appear to be partly redacted:

> The levels of K_2O in the North Dakota lignite ash are in the high end range found in many biomass fuels, such as wood and switch grass. However; the levels of Na_2O are much greater than that found in biomass or coal fired SCR applications. Different boiler types will affect deactivation. CERAM's experience with biomass applications that utilize a bubbling fluidized bed (BFB) boiler with the

[84] April 2010 North Dakota Prelim BACT Determination. Appendix D: Haldor and CERAM Statements.

SCR in a high dust arrangement have been successful because we were able to size the catalyst appropriately and take advantage of the lower flame temperature (e.g., less oxidized poisons), available sorbent (e.g., limestone) that can absorb a portion of the catalyst poisons and the fact that a large portion of the ash is entrained. Pulverized coal (PC), stoker and cyclone boilers in the high dust arrangement can lead to an increase in deactivation due to the higher local flame temperatures and areas of incomplete combustion that both can lead to a severe increase in oxidized poisons. Solutions to reduce catalyst deactivation have been to use low dust (e.g., catalyst downstream of a baghouse with sorbent injection) and tail end (e.g., downstream baghouse and scrubber) configurations. However, our experience on low dust and tail end biomass and incinerator applications with similar fuel characteristics have shown that increased deactivation will still occur compared to similar applications firing sub-bituminous and bituminous coals.

The high levels of Na_2O in the ash for the North Dakota lignite are not commonly found in sub-bituminous and bituminous coals which are fired with SCR systems. CERAM is unaware of any SCR application experience in the industry with this level and form of sodium in the ash. Sodium is a well known catalyst poison. In particulate form the effects of sodium can be controlled by maintaining warm and dry conditions on the catalyst at all times during layup. Allowing moist conditions on the catalyst will result in the particulate bound sodium leaching into the pore structure of the catalyst where catalyst poisoning will occur. Small aerosol particles can penetrate and neutralize active catalyst sites even in dry conditions.

Catalyst Deactivation

For this application we can assume that most of the ash will be removed; however catalyst deactivation will still occur due to gaseous constituents in the flue gas and from the small amount of ash that will reach the reactor. Even though this application maybe ether a low dust or tail end application it is not a "no dust" application. Deactivation can be caused by exposure to various catalyst poisons and fouling agents, such as alkaline metals, arsenic, sulfate compounds, silica and phosphorous compounds, hydrochloric and hydrofluoric acids, sodium and potassium in the ash, etc., that are formed during the combustion process. Catalyst installed in even low dust and tail end locations are poisoned from the exposure to the flue gas. Some of the potential catalyst poisons that could lead to deactivation of our catalyst are found in the mineral and trace analysis or can be controlled by temperature. The amount of sulfur dioxide, sulfur trioxide and sulfuric acid are a function of temperature, thereby if the temperature is controlled above the acid dew point then no problems should exist. In addition, the amount of lead, mercury, chromium and other metals listed in the trace analysis are typically extremely low and should not be major influencing factor for a coal fired application. Moreover, the high levels of phosphorous, sodium and potassium found in the mineral analysis will increase deactivation rates. Arsenic poisoning

> will occur, however the levels for which this can he attributed to are a function of the amount of calcium oxide present in the flue gas.

North Dakota points to these statements stating:[85]

> In their proposals to Minnkota, both companies have made statements that bring into question the technical feasibility of both LDSCR and TESCR (see Appendix D). CERAM has stated that it is unaware of any SCR application experience in the industry with the level and form of sodium in the M. R. Young Station ash. Haldor Topsoe has stated that the potential exists that physical deactivation due to catalyst blinding and plugging could be severe enough to make SCR a non-viable option for controlling NOx emissions.

We make the following observations regarding these catalyst vendor statements and North Dakota's interpretation of them:

- Both catalyst vendors statements are fragments from, and appear to have been pieced together from much larger reports that have been claimed as confidential. Consequently full context is unavailable. However, they are illuminating in comparison to the narrowly crafted statements extracted by Minnkota in January 2010 from these same catalyst vendors.

- Neither vendor states that either a LDSCR or TESCR configuration cannot be successfully implemented. In fact, Haldor Topsoe states that it, "believes that the low dust (after ESP) option is the most viable." As has been noted in several subsequent documents, Haldor Topsoe does state that, "[t]he tail-end option should be considered further with actual slip stream or mini reactor testing on an operating unit ..." However, it seems clear that it did not mean this statement as a condition for both LDSCR and TESCR configurations. This is evident from the remaining portion of the sentence: "but at this time HTI feels that with the data currently available [which includes the Microbeam Report] that the low dust option is the best option." This means to us that Haldor Topsoe is simply stating that further testing may reveal that a TESCR configuration would be a *better* option that a LDSCR configuration.

- CERAM notes its successful experience with a HDSCR installation on a biomass fired CFB boiler, but qualifies that a HDSCR installed on pulverized coal, stoker and cyclone boilers would result in higher deactivation. However, CERAM states that the solution to this has been to use LDSCR and TESCR configurations, accepting that even these configurations with high alkali fuels will result in higher catalyst deactivation in comparison to subbituminous and bituminous coals. CERAM also notes that the effects of sodium deactivation can be controlled "by maintaining warm and dry conditions on the catalyst at all times during layup." This does not appear to be a statement a catalyst supplier would make if it had concluded that a LDSCR or TESCR configuration would not be feasible.

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[85] April 2010 North Dakota Prelim BACT Determination. See page 9.

North Dakota focuses on Haldor Topsoe's statement, "the potential exists that physical deactivation due to catalyst blinding and plugging could be severe enough to make SCR a non-viable option for controlling NOx emissions." However, as we indicate above, the full statement is:

> HTI believes that the low dust (after ESP) option is the most viable. HTI feels that deactivation of the catalyst due to alkali poisoning (sodium) will be the biggest challenge. However, with that said, HTI also recognizes that chemical deactivation can generally be managed with the adjustment of catalyst volume and/or guarantee life while the potential exists that physical deactivation due to catalyst blinding and plugging could be severe enough to make SCR a non-viable option for controlling NOx emissions.

It does not appear to us that Haldor Topsoe's full statement indicates that it believes either a LDSCR or TESCR configuration is not technically feasible.

Our conclusion is that these catalyst vendors noted that a higher rate of catalyst deactivation for LDSCR and TESCR configurations would be expected in comparison to typical subbituminous or bituminous fuels, but that in and of itself would not be a disqualification. As we state elsewhere in our report, catalyst deactivation should be viewed not as a technical feasibility issue but as a cost-effectiveness issue. The potential increased cost of catalyst and catalyst regeneration is absorbed as an operational cost.

3.7.7 April 2010 North Dakota Prelim BACT Determination

This report[86] concludes that HDSCR is not technically feasible. North Dakota also states it has "significant concerns" whether LDSCR and TESCR are technically feasible.

North Dakota appears to have selectively given great weight to certain CERAM and Haldor Topsoe statements in their respective proposals to Minnkota (Appendix D). We review the CERAM and Haldor Topsoe statements and North Dakota's interpretation of them as part of our review of Appendix D.

Much of the remainder of material presented by North Dakota in its 2010 Preliminary BACT Determination concerns cost-effectiveness and as such is beyond the scope of this report, which focuses on the technical feasibility of SCR. However, there are some applicable discussions concerning the technical feasibility of SCR in the appendices,[87] which we discuss below.

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[86] Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2, April 2010, Division of Air Quality North Dakota Department of Health 918 E. Divide Avenue Bismarck, North Dakota. The Appendices have been downloaded from: https://www.regulations.gov/document?D=EPA-R08-OAR-2010-0406-0052. This report also includes the 2009 SCR Technical Feasibility Study within Appendix A, which we have previously reviewed.

[87] Note that some of the documents we discuss are marked as being confidential. However, all of the documents we discuss concerning the April 2010 North Dakota Prelim BACT Determination, including the appendices, were

3.7.8 Appendix C: September 2008 B&McD, Tackticks, and EERC Report

The beginning of the September 2008 B&McD report[88] reiterates much of the material covered in previous reports regarding the high content of alkali and/or alkaline earth metals of North Dakota lignite. B&McD then presents a discussion that centers on the point that catalyst guarantees do not cover the long term problem of complying with an emission limit. We note that the issue of long term compliance does not uniquely apply to a SCR installation on an EGU burning North Dakota lignite—any SCR operator would face the same issues. B&McD then defends the November 2004 EERC Slipstream Report and in fact later in its report devotes considerable space to it. As we have discussed the November 2004 EERC Slipstream Report previously, we will only note that for the reasons stated, we do not view that report as adding anything of real value to the issue of the technical feasibility of any SCR configuration, especially one in a low dust or tail-end configuration. Following this, B&McD spends considerable time criticizing the July 2008 Hartenstein Report. Most of this criticism involves various red herring assertions that have little to nothing to do with the two fundamental questions regarding North Dakota lignite SCR technical feasibility.

For instance, B&McD states, "Hartenstein did not demonstrate he had an understanding of Center lignite characteristics and variability issues." In fact, a number of reports that were available to all stake holders presented stack test and sampling data that were used by North Dakota, Minnkota, and its consultants to make alkali mass loading comparisons to published studies. Whether Mr. Hartenstein had an appreciation for Center lignite variability is beside the point. Mr. Hartenstein used the data that was available at the time and Minnkota had ample opportunity to present more or different data and incorporate it into record. Mr. Hartenstein addressed B&McD's criticisms in another part of Appendix C, which we cover in the next section.

Most of the remainder of B&McD's report consists of a rehashing of material already presented in prior reports with some new material concerning the mechanisms of alkali and/or alkaline earth metals catalyst deactivation. Much of the material was internally repetitious. We do not regard this document as presenting any new information that addresses the two fundamental questions regarding North Dakota lignite SCR technical feasibility – (1) What is the mass loading of alkali and/or alkaline earth metals a LDSCR and a TESCR would experience at a North Dakota lignite fueled EGU, and (2) What effect would these mass loadings have on catalyst life?

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obtained from EPA's Docket for its proposed and final regional haze actions at: https://www.regulations.gov/document?D=EPA-R08-OAR-2010-0406-0052.

[88] Comments and Responses to NDDH Regarding U.S. EPA Region 8's July 31, 2008 Comments and Plains Justice July 30, 2008 Comments on NDDH Preliminary NOx BACT Determination for Milton R. Young Station (MRYS), September 22, 2008.

3.7.9 Appendix C: October 2008 EPA Letter and Hartenstein Reply to B&McD, Tackticks, and EERC September 2008 Report

In its October 17, 2008 cover letter to North Dakota; transmitting Mr. Hartenstein's October 2008 reply to the B&McD, Tackticks, and EERC comments;[89] EPA states:

> EPA provided NDDH significant evidence that selective catalytic reduction (SCR) as a control option is technically feasible, particularly in a tail-end configuration. Minnkota and its contractors failed to address this point or provide any additional data or facts substantiating the claim that SCR is technically infeasible. In fact, in Appendix A to Minnkota's letter, Burns & McDonnell's subcontractor, Mr. Volker Rummenhohl of Tackticks LLC, never states that SCR would be technically infeasible at MRYS.

Mr. Hartenstein provides a similar summary:[90]

> The Document does not provide any new, previously unknown facts or offer any new technical arguments. Again, the majority of the Document is directed at HDSCR and still doesn't adequately substantiate the claim why TESCR is considered technically infeasible. While the Document discusses the various types of deactivation mechanisms in minute scientific detail, which were never disputed per se, it fails to address the rate at which this catalyst deactivation occurs in a TESCR system. This however is the most critical issue and no data is provided to answer this fundamental question.

We believe the above statements accurately describe the content of the September 2008 B&McD, Tackticks, and EERC comments. Mr. Hartenstein's report consists almost entirely in disputing various statements made by B&McD, Tackticks, or EERC. Below, we present several of Mr. Hartenstein's comments we feel are particularly pertinent to the issue:

> The Document misses the point that only the rate of catalyst deactivation remains in question rather than the undisputed fact that among other physical and chemical deactivation mechanisms pore pluggage and surface blinding can cause catalyst deactivation.[91]
>
> [A]bsolutely no data was offered to substantiate the claimed impact of aerosols on TESCR catalyst. No representative data quantifying and/or characterizing such aerosols downstream of an ESP and wet scrubber was provided (see also pages A 41 - A 45 of my original report). The data referenced from the Powerspan barrier

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[89] Appendix C October 17, 2008 Letter from EPA Region 8 to Terry O'Clair transmitting Hans Hartenstein Comments and Responses to NDDH Regarding U.S. EPA Region 8's July 31, 2008 Comments and Plains Justice July 30, 2008 Comments on NDDH Preliminary NOx BACT Determination for Milton R. Young.

[90] Remarks to the "Comments and Responses to NDDH Regarding U.S. EPA Region' 8's July 31, 2008 Comments and Plains Justice July 30, 2008 Comments on NDDH Preliminary NOx BACT Determination for Milton R. Young Station (MRYS)" dated September 22, 2008, by Hans Hartenstein. On Behalf of the United States Department of Justice, October 2008. See page 2 of 24.

[91] *Ibid*., page 4 of 24.

discharge reactor pilot slipstream testing is not relevant for TESCR as it was obtained on MRYS Unit 1 downstream of the ESP rather than on MRYS Unit 2 downstream of the wet FOD. Even though I never disputed that these aerosols will impact the catalyst in a TESCR, the quantity of such aerosols entering a TESCR must be expected to be extremely small, which means their deactivation effect will most likely be rather slow. Therefore, it can be expected with a very high degree of confidence that the catalyst lifetime in a TESCR will most certainly exceed 10,000 hours, which was randomly defined by the Department as a minimum time for successful operation.[92]

Catalyst poisoning studies in Europe associated with co-firing high alkali (Na and K) containing biomass have clearly shown an accelerated catalyst deactivation in HDSCRs compared to European bituminous coal-fired units.[11, 12] However, neither did this lead to the conclusion that HDSCR is technically or economically infeasible nor did such accelerated catalyst deactivation occur in TESCRs.[13,14] Units firing 100% biomass (i.e. wood and/or straw) with organically bound sodium and potassium contents as high or even higher than Center lignite have successfully operated even HDSCRs.[15,16] Wet bottom boilers equipped with TESCRs have experienced no effect on catalyst deactivation as a result of co-firing biomass in Europe.[17, 18] [93]

Footnotes to the above quote:

11 Cleaner Fossil Fuel For Sustainable Development, Co-Firing Coal and Biomass, a presentation by Hemik Noppenau, Elsam (Energie E2 until 07/01/2006), Denmark

12 Washing Your Own Catalyst, a presentation Nathan White, Haldor Topsoe, NOx Round Table 2007,Cincinnati, Ohio.

13 Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Term SCR Catalyst Experience and Cost," The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, 2005.

14 Considerations for Catalyst Deactivation and Regeneration When Firing Biomass, Dr. Greg Holscher, CERAM and Mark Ehmschwender, Evonik Energy Services, 2008 NOx Round Table, Richmond, Virginia.

15 Cleaner Fossil Fuel For Sustainable Development, Co-Firing Coal and Biomass, a presentation by Henrik Noppenau, Elsam (Energie E2 until 07/01/2006), Denmark.

16 Washing Your Own Catalyst, a presentation Nathan White, Haldor Topsoe, NOx Round Table 2007, Cincinnati, Ohio.

17 Sobolewski, H, H. Hartenstein, H. Rhein, "STEAG's Long Tenn SCR Catalyst Experience and Cost," The 2005 EPRI Workshop on Selective Catalytic Reduction, Louisville, KY, 2005.

18 Considerations for Catalyst Deactivation and Regeneration When Firing Biomass, Dr. Greg Holscher, CERAM and Mark Ehmschwender, Evonik Energy Services, 2008 NOx Round Table, Richmond, Virginia.

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[92] *Ibid.*, page 7 of 24
[93] *Ibid.*, page 7 of 24.

The biomass data provided in the [September 2008 B&McD, Tackticks, and EERC] Document is very useful as it offers some insight into the possible deactivation rates of a HDSCR that could be expected at MRYS. Since HDSCRs have been in operation on biomass fired boilers since 2001, [38,39] this allows some composition comparison of biomass (i.e. wood) and North Dakota lignite. The fuels listed in Tables 2 through 5 of the Document are mostly woods of various types. A comparison to North Dakota lignite is shown in the table below. As stated in the Document, wood is similar to North Dakota lignite in its composition and variability.

	Center lignite		Biomass (woods)	
	Historical	Future	Range	average
Heating value [10^6 Btu/lb]	13.2	13.4	6.8 - 9.1	8.3
Ash content [%wt.]	9.6	7.8	0.3 - 20.4	6.0
CaO [%wt. in ash]	13.2	17.0	5.8 - 49.9	20.9
K_20 [%wt. in ash]	1.3	1.0	0.2 - 22.4	7.7
MgO [%wt. in ash]	4.0	5.1	1.8 - 18.4	4.3
Na20 [%wt. in ash]	4.4	5.6	0.1 - 23.5	3.1

Likewise is the association of alkali and/or alkaline earth metals in Center lignite similar to the associations found in biomass. Thus, it seems to be not unreasonable to expect that the catalyst deactivation in HDSCRs installed on units burning 100% biomass of similar composition and variability should be similar to the one of catalyst in a HDSCR burning North Dakota lignite.

The deactivation rate of the HDSCR catalyst at Elsam's Avedoere Unit 2 was found to be about 25% per 8,000 HDSCR operating hours when burning 100% biomass (mostly wood and some straw) while it was found to be only about 10 - 11% per 8,000 HDSCR operating hours when burning 100% bituminous coal.[40] Thus, the catalyst deactivation was found to be about 2.5 times higher for biomass than for bituminous coal. However, a catalyst deactivation of around 25% per 8,000 HDSCR operating hours has also been observed for several units in the U.S., particularly for those burning high arsenic coal without limestone mitigation. *In other words the full scale HDSCR catalyst deactivation experience of a unit burning 100% biomass, which is very similar and therefore directly comparable to North Dakota lignite, was found to be virtually identical with the full scale HDSCR catalyst deactivation of many U.S. units burning high arsenic bituminous coal. Needless to say that the catalyst deactivation to be expected in a TESCR where virtually all of the fly ash associated particle-bound compounds have been removed upstream of the catalyst will be considerably less.*

There is no question that the flue gases from combusting North Dakota lignite will cause a relatively rapid catalyst deactivation of a HDSCR catalyst. However the rate of catalyst deactivation is indisputably a function of the mass flow of catalyst

poisons, which is dramatically reduced in a TESCR compared to a HDSCR. [94] [emphasis added]

Footnotes to the above quote:

37 Kramer, M., C. Gerlach, H. Hartenstein, " As_2O_3 and SO_3 Testing at Hoosier Energy's Merom Generating Station," The 2007 EPRI Workshop on Selective Catalytic Reduction, Pensacola, FL, 2007.

38 Cleaner Fossil Fuel For Sustainable Development. Co-Firing Coal and Biomass, a presentation by Henrik Noppenau, Elsam (Energie E2 until 07/01/2006), Denmark.

39, 40 Washing Your Own Catalyst, a presentation Nathan White, Haldor Topsoe, NOx Round Table 2007, Cincinnati, Ohio.

In the above quote, Mr. Hartenstein uses available data (which was also available to Minnkota and its consultants) to address the two fundamental questions regarding North Dakota lignite SCR technical feasibility (see above italicized text). The remainder of Mr. Hartenstein's October 2008 report is concerned with disputing various red herring assertions made by B&McD, Tackticks, and EERC which largely concern European SCR experience.

3.7.10 Appendix C: November 2008 B&McD, Fuel Tech, and EERC Report

In its November 17, 2008 report, B&McD, Fuel Tech,[95] and EERC respond to the October 2008 EPA Letter and Hartenstein Reply to the previous B&McD, Tackticks, and EERC September 2008 Report.[96] B&McD cites to several publications to support its assertion that scrubbers do not effectively remove submicron particles of sodium and potassium. These submicron particles, existing in a gas phase, then continue downstream to deactivate SCR catalyst. It also presents evidence of these submicron being collected of the ESP at Milton R. Young.[97] Following this, B&McD associates the high alkali and/or alkaline earth metals in North Dakota lignite to biomass firing and studies that conclude that catalyst deactivation will occur, including those previously cited by North Dakota in its BACT analyses (e.g., Zheng (2005) and Kling (2007)).

However, B&McD makes no attempt to actually use any of this information to address the two fundamental questions regarding North Dakota lignite SCR technical feasibility: (1) What is the mass loading of alkali and/or alkaline earth metals a LDSCR and a TESCR would experience at North Dakota lignite fueled EGU, and (2) What effect would these mass loadings have on catalyst life? In fact, B&McD discounts catalyst vendor guarantees stating, "one of the queried vendors stated 'the fly ash constituents that can poison the catalyst will have been removed from the flue gas stream by the existing ESPs.' This statement fails to recognize that submicron aerosols will pass through the electrostatic precipitator (ESP) and further ignores that a wet flue gas desulfurization ("scrubber") system upstream of a tail-end SCR is largely ineffective at

[94] *Ibid.*, page 13 of 24.
[95] After the September 2008 B&McD, Tackticks, and EERC report, Fuel Tech acquired Tackticks.
[96] Responses to Hans Hartenstein's October 2008 Remarks to September 22, 2008 Comments & Responses on NDDH Preliminary NOx BACT Determination for Milton R. Young Station (MRYS), November 17, 2008.
[97] *Ibid.* Pages 2 – 10.

removing such aerosols."[98] Again, the issue, as recognized by Mr. Hartenstein is not whether catalyst deactivation will occur but the rate of deactivation: "While the Document discusses the various types of deactivation mechanisms in minute scientific detail, which were never disputed *per se*, it fails to address the rate at which this catalyst deactivation occurs in a TESCR system."[99]

B&McD then devotes a number of pages rebutting Mr. Hartenstein's October 2008 comments, but presents no new information that addresses the two fundamental questions regarding North Dakota lignite SCR technical feasibility.

The November 2008 B&McD, Fuel Tech, and EERC Report also contains Appendix A, which is a separate six page report by Fuel Tech's Volker Rummenhohl on catalyst poisoning. This report includes general remarks on catalyst deactivation and various criticisms of Mr. Hartenstein's experience and knowledge. Again, no information was presented that addressed the two fundamental questions regarding North Dakota lignite SCR technical feasibility.

3.7.11 Appendix C: February 2009 B&McD and Steve Benson Supplemental Report

This report, prepared by B&McD and Steve Benson is stated to be a review of and response to technical literature provided by North Dakota regarding submicron particle collection and penetration for dry ESPs.[100] B&McD and Benson proceed by discussing the inefficiency of ESPs and FGDs in capturing submicron particles. A number of sources supporting this conclusion are presented. B&McD and Benson then review the form of sodium particulate present in the exhaust gas at Milton R. Young from burning Center Mine lignite, concluding that vaporized forms predominate. B&McD and Benson present information on the particulate mass loadings of various particulate size fractions at the Boswell Energy Station when it fired high-sodium, lower-ash northern Powder River Basin subbituminous coal. They concluded that the scrubber is inefficient in removing submicron sized particles and the particulate collected downstream of the Boswell scrubber was coal-related and caused by the high sodium content of the coals. B&McD and Benson then present information from a DOE test of the stack emissions from three EGUs that indicated that the one that burned North Dakota lignite – Coal Creek, experienced the highest stack emissions rate.

B&McD and Benson then describe Powerspan slipstream electrocatalytic oxidation reactor testing conducted in July 2007 of the exhaust gas at Milton R. Young Unit 1 downstream of the ESP. They noted that the instrument became fouled due to elemental sodium, sulfur, and calcium in the ash after 16 days of testing. This is followed by a discussion of testing conducted in 1983 by Markowski on the Milton R Young in which the mass concentration of particulate matter by size fraction was sampled at the inlet and outlet of the scrubber. B&McD and Benson

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[98] *Ibid.* Page 14.

[99] Remarks to the "Comments and Responses to NDDH Regarding U.S. EPA Region' 8's July 31, 2008 Comments and Plains Justice July 30, 2008 Comments on NDDH Preliminary NOx BACT Determination for Milton R. Young Station (MRYS)" dated September 22, 2008, by Hans Hartenstein. On Behalf of the United States Department of Justice, October 2008. See page 2 of 24.

[100] Supplemental Information for Consideration Regarding NOx BACT for M.R. Young Units 1 and 2: Technical Feasibility Issues for TESCR or LDSCR Retrofit February 20, 2009.

again conclude that the Markowski data indicate that scrubbers are not effective at removing submicron particulate.

In general, we do not dispute the observation that a typical EGU's ESP and scrubber cannot remove all particulate matter. As the July 2009 Microbeam report itself indicates, "[a] significant fraction of the particulate was removed by the ESP, with a removal efficiency of 99.76%."[101] Thus, there is not much particulate matter left for a scrubber to remove. None of this information was related to the mass loadings at any SCR configuration point at the Milton R. Young.

Following these discussions, B&McD and Benson actually identify the two fundamental questions regarding North Dakota lignite SCR technical feasibility:[102]

> The first fundamental issue is "how to estimate the amount (mass rate) of sodium and in what size range could be emitted from the boilers at MRYS, for the purposes of a BACT analysis." Because BACT analyses on existing sources are not common, we also presume them to be "studies on paper using available information." We do not consider BACT analyses as research projects requiring design of experiments, site-specific testing, and development engineering for the control technique being considered. Thus, this first issue is a significant challenge.
>
> The second fundamental issue is "for the purposes of a BACT analysis, what rate of catalyst deactivation is likely to occur as a result of exposure to the expected particle or aerosol size range and concentration of sodium emitted from a boiler over a given period of time?"
>
> Only by assuming that these fundamental issues can be resolved with the degree of certainty required for purposes of a BACT analysis, can such a comparison then be performed that could lead to a basis of technical feasibility of low-dust and tail-end SCR technology for MRYS.

As we discuss in our review of the May 2009 North Dakota SCR BACT Feasibility Report, North Dakota did not conclude that estimating "the amount (mass rate) of sodium and in what size range could be emitted from the boilers at MRYS" to be "research projects requiring design of experiments, site-specific testing, and development engineering for the control technique being considered." In its May 2009 North Dakota SCR BACT Feasibility Report, North Dakota reviewed August 2007 and May 2008 stack testing performed at the Milton R. Young Unit 2, and the same Markowski data that B&McD and Benson discuss.[103] In so doing, North Dakota conservatively estimated that the total emission rate for sodium and potassium sulfate combined

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[101] July 2009 Microbeam Report. See page 2. Note that although Microbeam uses this information to conclude, "[t]hese results show very little overall removal of the submicron particulate across the wet scrubber system," clearly, there is little particulate matter after the exhaust gas exits the ESP, regardless of size. Again, the focus should be to address the two primary questions regarding North Dakota lignite SCR technical feasibility.
[102] *Ibid.,* Page 33.
[103] See page 22 of the May 2009 North Dakota SCR BACT Feasibility Report.

that is less than or equal to 0.1 micrometers in size is 0.98 mg/Nm^3, of which 0.78 mg/Nm^3 is sodium sulfate. North Dakota then compared these data to the data in the Zheng and Kling reports (cited repeatedly by B&McD in its various reports) and conservatively concludes that the rate of catalyst deactivation for a North Dakota lignite SCR installation would be substantially slower than reported by the Zheng and Kling studies. It uses this information to conclude that both LDSCR and TESCR are technically feasible. Minnkota and its various consultants had access to the same information but apparently chose not to make similar calculations.

We note that Mr. Hartenstein seems to conclude this type of simplified calculation is overly conservative, reasoning that the alkalis in question are not mobile, get cleaned out by the scrubber, and are not at the right temperatures, among other reasons.[104]

Instead, B&McD and Benson note a lack of data and qualitatively review the literature concerning boilers burning high alkali and/or alkaline earth metals biomass, including the Kling study, and U.S. EGUs that have concluded that HDSCR and TESCR configurations are technically feasible.[105] Also unlike the May 2009 North Dakota SCR BACT Feasibility Report, B&McD and Benson do not review the four biomass fired boilers equipped with TESCR or LDSCR that were currently in operation in the United States.[106]

Our Conclusions Regarding the April 2010 North Dakota Prelim BACT Determination

We believe we have reviewed all of the documents in the public record regarding North Dakota's April 2010 Preliminary BACT Determination concerning the technical feasibility of installing SCR on EGUs burning North Dakota lignite. Our conclusions are as follows:

- All parties recognized that there are two fundamental questions regarding North Dakota lignite SCR technical feasibility: (1) What is the mass loading of alkali and/or alkaline earth metals a LDSCR and a TESCR would experience at North Dakota lignite fueled EGU, and (2) What effect would these mass loadings have on catalyst life?

- Minnkota and its consultants' strategy appears to have consisted of (1) qualitatively emphasizing the catalyst deactivation potential of North Dakota lignite, (2) avoiding making any calculations concerning potential catalyst deactivation rates and not responding to the calculations North Dakota made, (3) discounting European high-alkali SCR experience, (4) engaging in assertions designed to distract from the two fundamental questions, and (5) extracting narrow and overly restrictive statements from catalyst vendors.

- It appears that the issues that most weighed on North Dakota's determination were their interpretations of statements made by the two catalyst vendors in their proposals to Minnkota, and the July 2009 Microbeam Report. As we discuss above, we do not believe that the catalyst vendors statements indicate they considered LDSCR or TESCR unviable

[104] See the July 2008 Hartenstein Report, page A-27.
[105] These are the Mercer Station and the South Oak Creek stations which are configured differently and are noted to burn different coals. We do not dispute the differences are significant.
[106] See page 28 of the May 2009 North Dakota SCR BACT Feasibility Report.

at Milton R. Young. Also, as we discuss in our separate treatment of the 2009 Microbeam Report, we conclude that although a considerable amount of data was collected and reported by Microbeam, its report does little to address the two fundamental questions regarding technical feasibility of SCR on a North Dakota lignite EGU. Therefore, we consider North Dakota's concern misplaced and improperly weighed in relation to the previous record it established in its previous BACT analyses that LDSCR and TESCR were technically feasible.

3.8 November 2010 North Dakota Milton R. Young BACT Determination

The main document in the November 2010 North Dakota Milton R. Young BACT determination is the Nov 2010 North Dakota BACT Finding of Fact.[107] This document is only 14 pages in length and contains only 11 documents in its references list. Indeed, after the front matter, background information, and a summary of the BACT requirements and procedures, the document consists of North Dakota listing 24 findings for LDSCR and TESCR, and 12 findings for HDSCR, before making its determination that NOx BACT for Milton R. Young is Selective Non-Catalytic Reduction (SNCR) and Advanced Separated Overfire Air (ASOFA). These findings are top-line summary interpretations of some but not all of the issues discussed at length in prior documents. These findings mainly fall into two categories: (1) issues related to the high alkali and/or alkaline earth metals in North Dakota lignite causing catalyst deactivation, and (2) North Dakota's interpretation of statements made in catalyst vendor correspondence and proposals. However, there are a number of key findings that appear to have originated in handwritten notes taken during calls between North Dakota and CERAM and Haldor Topsoe representatives.[108] The assertions contained within these notes have no other documentation. We discussed them in our review of the vendor correspondence earlier.

North Dakota does not present any information to contradict the calculations and other technical determinations it presented in its earlier works in which it determined that the mass loadings for LDSCR and TESCR configurations would be so low as to result in acceptable catalyst deactivation rates.[109] It states that its "2008 analysis only evaluated one concentration of sodium and potassium in the flue gas. This concentration did not account for worst case conditions." North Dakota does not further explain what those worst case conditions are, what data supports them, or how its earlier work did not account for them. It also states that "the vendors indicated that the flue gas characteristics may be worse than the biomass boilers the Department evaluated where TESCR has been applied." As we indicated in our assessment of the April 2010 North Dakota Prelim BACT Determination, we cannot access most of the catalyst vendor statement because despite being separated into confidential and non-confidential material, even the non-confidential material was apparently claimed as confidential and is not accessible. Because if

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[107] Findings of Fact for Best Available Control Technology Determination for Control of Nitrogen Oxides for M.R. Young Station Units 1 and 2, November, 2010, ND Department of Health.

[108] See the file, https://www.regulations.gov/contentStreamer?documentId=EPA-R08-OAR-2010-0406-0314&attachmentNumber=12&contentType=pdf, which appears to be hand written notes concerning call records between North Dakota and CERAM. Notes appear to have been made from four different people, some of who did not attend both calls. No date appears for the CERAM call but the Haldor Topsoe call was dated either 7/15/2010 or 9/15/2010.

[109] See for example, our review of the May 2009 North Dakota SCR BACT Feasibility Report and the July 2009 North Dakota SCR BART Report.

this, we cannot verify these claims. We note that the 2009 Microbeam report accompanied Minnkota's requests for proposal to these vendors. However, as we discuss in our assessment of the 2009 Microbeam Report, although the Microbeam results do not provide much information (with the exception of Figure 23) concerning the mass loading of alkali and/or alkaline earth metals after the scrubber, they do indicate that the total PM loading was measured to be 1.08 X 10^4µg/dscm. Converting this figure to mg/Nm^3, results in a value of 10.8 mg/Nm^3, which is less than 2% more than the mass loading North Dakota considered. Because this information was part of the design information supplied to the vendors, the source of the "worst case conditions" North Dakota mentions remains a mystery.

We do not dispute the evidence in the public record that the high alkali and/or alkaline earth metals content of North Dakota lignite will cause catalyst deactivation. Any coal or lignite will cause some degree of SCR catalyst deactivation regardless of configuration or fuel chemistry. The two fundamental questions regarding North Dakota lignite SCR technical feasibility attempt to get to address the degree of catalyst deactivation. Unfortunately, despite the extensive data collection efforts that have occurred at the Milton R. Young facility, Minnkota has steadfastly refused to address these questions, except in a general qualitative manner.

Most of the remaining LDSCR and TESCR findings that are pertinent to our report concern North Dakota's interpretation of statements from catalyst vendors CERAM and Haldor Topsoe. We address those issues in our review of the vendor correspondence.

3.9 Review of September 2011 North Dakota SIP-FIP proposal

Here, we review the key material used by EPA Region 8 to conclude SCR was feasible for North Dakota lignite EGUs in its September 2011 proposal.[110] This includes EPA's TSD, and the Fox Leland Olds SCR report. Other issues concerning regional haze and North Dakota's SIP that are not related to the technical feasibility of North Dakota lignite SCR are not covered.

North Dakota's February 24, 2010 SIP included a supplement dated July 28, 2010 and an amendment dated July 28, 2011. Almost all of the information pertaining to North Dakota's revised position that SCR was technically infeasible was based on that July 28, 2011 amendment, which included its November 2010 BACT determination.

In its September 21, 2011 action, EPA proposed to disapprove North Dakota's NOx BART determinations for Leland Olds Unit 2, and Milton R. Young Units 1 and 2. Among other objections, EPA disagreed with North Dakota's determinations that SCR was infeasible and EPA presented considerable information demonstrating that the facility's cost-effectiveness of LDSCR and TESCR (accepted by North Dakota) were greatly inflated. EPA proposed that BART for these units was SCR (configuration left to facility).[111]

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[110] See 76 FR 58570 (September 21, 2011).

[111] Due to a significant error EPA discovered in the cost-effectiveness of Coal Creek Units 1 and 2, EPA also proposed to disapprove North Dakota's determination that SCR was not cost-effective. In this case, EPA proposed to find that NOx BART was SNCR with SOFA and LNB. Because this proposal does not relate to the technical feasibility of SCR on North Dakota lignite, it not further discussed.

EPA's rejection of North Dakota's arguments against technical infeasibility was based on the following points:[112]

- The BART Guidelines go on to state that a control technology is technically feasible if it is "available" and "applicable."

- SCR technology has been available for many years so there was no need for Minnkota to conduct extended trials.

- EPA concluded that given that SCR has been deployed at hundreds of EGUs, burning a wide variety of coals, it is presumed that it is applicable to the coal-fired EGUs at Milton R. Young Station.

- Minnkota and North Dakota's concerns relate only to the specific length of catalyst life and not to commercial availability. Catalyst deactivation is a cost issue, not a technical feasibility issue. EPA cited the BART Guidelines directive: "Where the resolution of technical difficulties is merely a matter of increased cost, you should consider the technology to be technically feasible."[113]

- Although the North Dakota gives great weight to two catalyst vendors being unwilling to provide typical catalyst life guarantees without catalyst deactivation field tests, the BART Guidelines, states "lack of a vendor guarantee by itself does not present sufficient justification that a control option or an emissions limit is technically infeasible.[114]

- Neither vendor indicated it would not provide SCR catalyst absent any prior field testing. One vendor was willing to provide full performance guarantees on critical operating parameters such as NOx reduction, NH_3 slip, SO_2 to SO_3 conversion, and pressure drop. This is strong evidence that at least one of the two catalyst vendors believed that NOx could be successfully controlled with SCR, thus SCR is commercially available.

- Both catalyst vendors stated they believe a catalyst life guarantee can be offered once the field testing data is collected.

- EPA pointed out that these two catalyst vendors positions were not in conflict with North Dakota's prior BACT determination that LDSCR and TESCR were technically feasible (as discussed in our review of May 2009 North Dakota SCR BACT Feasibility Report) due to:

    - The fact that the ESP would remove greater than 99% of the particulate matter, including catalyst poisons, and North Dakota found that the resultant loadings of alkali and/or alkaline earth metals , at LDSCR and TESCR configurations were

[112] Summarized from 76 FR 58604 – 58605 (September 21, 2011).
[113] See 40 CFR part 51, Appendix Y, section IV.D, step 2.
[114] Ibid.

significantly lower than those in the gas streams of boilers burning peat and wood that were the subject of experimental and pilot scale testing of SCR catalyst life.

- North Dakota concluded that a reasonable catalyst life could be achieved at Milton R. Young.[115] Id. North Dakota independently consulted three vendors who opined to the State that SCR would be technically feasible at Milton R. Young Station. Finally, the State found that existing biomass boilers, with flue gas characteristics that approximate those from North Dakota.

- Microbeam's July 2009 Report demonstrated that the ESP removes at least 98% of the catalyst poisons, before they could reach a LDSCR or TESCR.

Two key points of EPA's conclusions regarding technical feasibility were (1) catalyst life is a cost issue, not a technical feasibility issue, and (2) the two catalyst vendors' concerns regarding testing rested not on a threshold question of whether SCR would work at Milton R. Young, but simply on the length of their catalyst life guarantee.

EPA also addressed the issue of the conditions under which the small amount of alkali and/or alkaline earth metals that remained downstream of the ESP would potentially be a concern. EPA indicated:[116]

> [A]any remaining soluble alkaline substances would not poison the catalyst at TESCR operating temperatures. Significant deactivation only occurs if condensed moisture is present at the catalyst surface, i.e., when the catalyst is being cooled down to below the water dew point. Unit startups and shutdowns do not occur frequently at Milton R. Young Station 1. Furthermore, condensation on the catalyst can be prevented by bypassing or buttoning up the SCR reactor during forced outages of a few days.[117]

We also reviewed EPA's March 2011 Fox SCR Report for Leland Olds.[118] In that report, Dr. Fox examines the record to that point regarding catalyst deactivation. She addresses catalyst deactivation from North Dakota lignite, which we summarize below:

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[115] EPA stated it didn't agree with North Dakota's arbitrary 10,00 hour catalyst life requirement for technical feasibility, stating again that catalyst life is an input to cost.

[116] See 76 FR 58607 – 8 (September 21, 2011).

[117] EPA's footnote to this quote was to cite a 5/6/08 e-mail, in which CERAM (one of the two catalyst vendors in question) stated "[d]ue to the high sodium and iron concentrations it is recommended that a full SCR bypass system be installed. During lay-up periods the catalyst would need to remain warm and dry (above condensing conditions), for instance with an air drying or dehumidification system. This may necessitate the use of a dehumidifier and air lock system to access the reactor. Thus, one of Minnkota's own potential catalyst vendor acknowledged that alkali-caused catalyst deactivation can be controlled by temperature and humidity control.

[118] March 2011 Revised BART Cost Effectiveness Analysis for Tail-End Selective Catalytic Reduction at the Basin Electric Power Cooperative Leland Olds Station Unit 2 Final Report Prepared for U.S. Environmental Protection Agency Region 8 Air Quality Planning Unit 1595 Wynkoop Street Mail Code: 8P-AR Denver, CO 80202-1129 Prepared by Phyllis Fox, Ph.D., PE (Consultant).

- Most of the arguments used to argue that catalyst deactivation will rapidly occur are based on data collected at boiler exits, which would not apply to a TESCR configuration, due to removal by the ESP and wet scrubber.[119]

- Any remaining soluble alkaline constituents do not poison the catalyst at tail-end SCR operating temperatures. Significant deactivation only occurs if condensed moisture is present at the catalyst surface, i.e., when the catalyst is being cooled down to below the water dew point. This does not happen very often at a base-loaded unit such as Leland Olds and can be prevented by bypassing or buttoning up the SCR reactor during forced outages of a few days. Regardless, catalyst vendors have ample experience preventing moisture condensation in SCR catalysts.[120]

- Dr. Fox notes a number of flaws with slipstream reactor tests and cites to a number of personal communications from Haldor Topsoe to that effect. She also notes that the slipstream testing described in the November 2004 EERC Slipstream Report on the Coyote, Columbia and Baldwin Facilities used a pitch that was too small for the ash loading and ash characteristics, causing plugging. Despite being frequently cited by Minnkota and its consultants as predictive of plugging at Milton R. Young, Dr. Fox noted that actual full-scale SCR operational experience at Baldwin does not replicate or bear that out.

- Finally, Dr. Fox notes the long history, going back to the 1980s, of EGU operators arguing that SCR is not technically feasible on different types of coals and lignites. However, successful SCR installations on many coal-fired EGUs has proven these arguments meritless.[121]

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[119] Dr. Fox cites to a 5/30/07 (Alstom) Letter in 5/8/08 Milton R. Young Additional Information, p. 2 (As to high dust SCR, a worst case: " Based on our experience with wood fired units, a hot side ESP is effective in removing the fly ash compounds that result in catalyst poisoning...the fly ash constituents that can poison the catalyst will have been removed from the flue gas stream by the existing ESPs.."). Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility North Dakota's NOx BACT Determination for Milton R. Young Station Units 1 & 2, May 8, 2008 (5/8/08 Milton R. Young Additional Information).

[120] Dr. Fox cites to a 5/6/08 Cochran (CERAM) email, p. 2 (as to high dust SCR:, a worst case: "Due to the high sodium and iron concentrations it is recommended that a full SCR bypass system be installed. During lay-up periods the catalyst would need to remain warm and dry (above condensing conditions), for instance with an air drying or dehumidification system. This may necessitate the use of a dehumidifier and air lock system to access the reactor."), in 5/8/08 Milton R. Young Additional Information. Dr. Fox also cites to Minnkota Power Cooperative, Inc. and Square Butte Electric Cooperative, Additional Information and Discussion of Vendor Responses on SCR Technical Feasibility, North Dakota's NOx BACT Determination for Milton R. Young Station Units I & 2, Appendix A, Vendor Emails, Email from John Cochran, CERAM Environmental, Inc., to Robert Blakley, Re: Request for Lignite SCR Feasibility Commercial and Technical Information, May 6, 2008 ("Sodium is a catalyst poison. Concerns reported by Dr. Benson regarding high sodium content and fine fume are duly noted, but inadequate evidence is presented that this could be a fatal flaw to application of SCR considering the flawed pitch and resultant pluggage of the catalyst used during the Coyote Station testing [North Dakota lignite]. Sodium is not a poison to catalyst at SCR operating temperatures. Significant deactivation can occur if condensed moisture transports sodium residing at the surface into the catalyst pore structure during outage or layup. CERAM has experience with high sodium applications to substantiate this effect. Important to avoid deactivation from sodium is the need to protect the catalyst from going through a condensation event.").

[121] Dr. Fox cites to a letter from Michael G. Phillips, Alstom, to Robert Blakley, Bums & McDonnell, Re: Request for SCR Information Milton R. Young Units 1&2, May 30, 2007, p. 1 ("ND lignite does create many challenges for

Our Conclusions Regarding EPA's September 21, 2011 Proposal

We conclude that EPA's proposed decision was based on a very thorough and fair understanding of the record. That included citations of statements by Dr. Fox in her report from catalyst vendors—including those engaged by Minnkota to provide proposals—opining that SCR was technically feasible on North Dakota lignite EGUs. Drawing on this information, EPA correctly reasoned that SCR was "available" and "applicable" as defined by the BART Guidelines. EPA correctly concluded that catalyst life is a cost issue, not a technical feasibility issue. EPA correctly noted that Minnkota's own information demonstrated that the amount of potential catalyst poisons left in the exhaust gas stream at Milton R. Young after the ESP would be very low and manageable and that North Dakota's prior determination that LDSCR and TESCR were technically feasible should have been unaffected by the two catalyst vendors requirement for testing prior to a full catalyst guarantee.

3.10 December 2011 Milton R. Young BACT Litigation

On December 21, 2011, the United States District Court for the District of North Dakota Southwestern Division upheld North Dakota's determination that SNCR is BACT for Milton R. Young.[122] We have reviewed the record list for this decision, consisting of 259 items, comprising much of the public record established up to this time.[123] Below we discuss the record on which the Court based its findings regarding the technical feasibility of SCR at Milton R. Young, which are essentially identical to the findings of fact presented in North Dakota's BACT determination for Milton R. Young.[124] As we discuss below, we believe the Court was not presented with a full and accurate record and some information was not presented in proper context.

Milton R. Young is Not a New and Dissimilar Source Type Category

Contrary to the state's 2010 findings, Milton R. Young is not a "new and dissimilar source type category" from other boilers where SCR had been applied." We disagree with this conclusion. There is a great deal of evidence in the record to conclude that the alkali content of the North Dakota lignite burned at Milton R. Young is either not significantly higher, or in some cases actually lower, than other fuels on which SCR has been successfully deployed. In fact, some of this evidence was actually presented by North Dakota itself. We discuss that evidence below.

SCRs, but even with all those challenges, it is possible to use ND lignite if the system is designed properly ..."), p. 2 ("Fuels high in sodium and potassium require special selection of catalyst, but can be treated by SCR.") in 5/8/08 Milton R. Young Additional Information.

[122] Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365.

[123] Most if not all of these items are available in EPA's docket, ID: EPA-R08-OAR-2010-0406.

[124] *See generally* Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365. See page 18.

- As we indicate in our review of the May 2009 North Dakota SCR BACT Feasibility Report, North Dakota itself indicates that "[b]iomass fired boilers have flue gas characteristics that more closely approximate those from North Dakota lignite. At least four biomass boilers that are equipped with tail end or low dust SCR are currently in operation in the United States." North Dakota then goes on to list them and it notes that several others are planned both in the U.S. and in Europe.[125] Just after this, North Dakota notes: "No data has been found from an actual operating facility which has similar flue gas characteristics to M.R. Young Station that use high dust, low dust or tail end SCR. However, experimental and pilot scale testing by Kling and Zheng provides empirical data for comparison." North Dakota concludes by stating, '[e]Existing biomass boilers are using LDSCR successfully. Although the boilers are not cyclone fired units, the New Hampshire units use similar PM control devices as M.R. Young Station (i.e. ESP). The potassium chloride emitted from the biomass boilers is a much more potent catalyst poison than the sodium sulfate emitted at the MRYS. The Whitefield Plant has operated for more than four years without deactivation problems." North Dakota uses the similarity of North Dakota lignite to biomass fueled boilers, along with the first set of vendor guarantees (which we discuss below) to conclude that TESCR and LDSCR are technically feasible. North Dakota also conservatively calculated the mass loading of alkali constituents LDSCR catalyst would experience at Milton R. Young, compared it to the deactivation rates in the same Zheng and Kling studies, and concluded that the catalyst deactivation rates at Milton R. Young would be lower, and thus acceptable.[126] Despite later concluding that all SCR configurations are not technically feasible, *North Dakota has not refuted this earlier position, which was a formerly a key input to its decision making.* This same information was presented in the July 2009 North Dakota SCR BART Report. Thus, North Dakota's own calculations and positions indicate that it has never concluded that the exhaust gas stream at Milton R. Young presented a "new and dissimilar source type category."

- In making its alkali mass loading calculations discussed above, North Dakota uses an average PM emission rate of 10.61 mg/Nm^3 at 6% O_2 from a then recent PM stacks test for Milton R. Young Unit 2. As we have indicated in our review of the July 2009 Microbeam Report, although Microbeam avoids such a comparison, we noted that the total PM loading of 10.8 mg/Nm^3 Microbeam reports was less than 2% more than the mass loading North Dakota considered. Thus, the 2009 Microbeam Report reinforces one of North Dakota's key findings: that the alkali mass loading a LDSCR (and hence a TESCR since it would be lower) would be expected to be lower that the deactivation rates reported in the Zheng and Kling reports which are so often cited by North Dakota and Minnkota's consultants.

- Although other U.S. coal-fired EGUs fitted with SCRs do not typically burn high alkali coals, they do burn other coals with different constituents which cause catalyst deactivation. For instance, as we indicate in our review of the July 2008 Hartenstein Report, Mr. Hartenstein concludes "the full scale HDSCR catalyst

[125] See page 28 of the May 2009 ND SCR BACT Feasibility Report.
[126] *Ibid.,* page 25.

> deactivation experience of a unit burning 100% biomass, which is very similar and therefore directly comparable to North Dakota lignite, was found to be virtually identical with the full scale HDSCR catalyst deactivation of many U.S. units burning high arsenic bituminous coal. Needless to say that the catalyst deactivation to be expected in a TESCR where virtually all of the fly ash associated particle-bound compounds have been removed upstream of the catalyst will be considerably less. There is no question that the flue gases from combusting North Dakota lignite will cause a relatively rapid catalyst deactivation of a HDSCR catalyst. However the rate of catalyst deactivation is indisputably a function of the mass flow of catalyst poisons, which is dramatically reduced in a TESCR compared to a HDSCR.[127]" As we have indicated throughout this report, all parties acknowledge that North Dakota lignite will cause some catalyst deactivation. The only real issue is the rate of that deactivation, which is tied to the mass flow rate of the alkali constituents at LDSCR and TESCR configurations—an issue which Minnkota and its consultants have assiduously avoided.

Thus, although the sodium content in North Dakota lignite is higher than what is burned at other EGUs that have successfully deployed SCR units, North Dakota found that the total alkali content (including potassium, a more potent catalyst deactivator) was not expected to result in higher than both experimental catalyst deactivation rates, that North Dakota has found to be acceptable. North Dakota also found that real world boilers that burn biomass had SCR units that have been successfully operating. Therefore, an EGU burning North Dakota lignite would not be a "new and dissimilar source type category."

As our review has indicated, most of the material Minnkota and its consultants have presented in their various reports, which the Court has referred to as "voluminous technical details,"[128] is concerned with reinforcing the point that North Dakota lignites have high alkali contents which will deactivate SCR catalyst to some degree. No party has disputed this fact. Unfortunately, it appears this information has been represented to the Court as being determinative of the two fundamental questions, when in reality Minnkota and its consultants have assiduously avoided addressing those questions..

<u>The Catalyst Vendor Statements Make Clear SCR's Feasibility</u>

North Dakota's 2010 findings mischaracterize catalyst vendors as being unwilling to guarantee the feasibility of SCR at lignite facilities. In fact, the "actual information" Minnkota supplied the two catalyst vendors, CERAM and Haldor Topsoe was inflated particulate mass loading figures. These vendors, having no understanding of the regulatory guidance and policy ignored by Minnkota, accepted them at face value, and wrongly assumed that Mr. Hartenstein had either not

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[127] Remarks to the "Comments and Responses to NDDH Regarding U.S. EPA Region' 8's July 31, 2008 Comments and Plains Justice July 30, 2008 Comments on NDDH Preliminary NOx BACT Determination for Milton R. Young Station (MRYS)" dated September 22, 2008, by Hans Hartenstein. On Behalf of the United States Department of Justice, October 2008. See page 13 of 24.

[128] Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365. See page 18.

submitted correct information or misled them. It appears that North Dakota did not catch this error. Thus, the vendor's views were wrongly memorialized in North Dakota's CERAM and Haldor Topsoe call notes, and incorporated it into its pleadings to the Court. All of the previous accumulated evidence that at least LDSCR and TESCR are in fact technically feasible at Milton R. Young, including the opinions of a number of other SCR equipment vendors and catalyst vendors which have never been retracted, was ignored.

CERAM and Haldor Topsoe Questioned the Life of the Catalyst, not the Feasibility of SCR

North Dakota also misinterpreted the CERAM and Haldor Topsoe refusals to provide catalyst life guarantees as evidence that SCR was not "available" under BACT. As we indicate in our review of EPA's September 2011 ND SIP-FIP proposal, the two catalyst vendors' concerns regarding testing rested not on a threshold question of whether SCR would function at Milton R. Young, but simply on the length of their catalyst life guarantee. In other words, SCR has been "available" as defined under BACT and the only issue has been how long of a catalyst life guarantee these vendors were willing to provide. As we have discussed elsewhere, catalyst life is not a technical feasibility issue, but rather it is a cost issue and should be properly addressed in the cost-effectiveness calculation.

Mr. Hartenstein's RFP was not Deceptive

The Court accepted North Dakota's characterization of Mr. Hartenstein's RFP as being deceptive when it stated, "In the spring of 2010, it became clear to North Dakota that the EPA's solicitation omitted key information about the units under consideration. When the vendors were presented with actual information about the units for which they had offered a "guarantee," they abruptly withdrew the guarantees."[129] However, as we demonstrate in Section 3.7, concerning our review of catalyst vendor correspondence, none of Mr. Hartenstein's correspondence with vendors was deceptive. Thus, we conclude that the Court was presented with inaccurate information regarding this.

Vendors Willing to Provide Catalyst Guarantees

Contrary to the state's 2010 factual findings that vendors are not willing to provide catalyst life guarantees, a number of SCR equipment and catalyst vendors had stated they considered SCR technically feasible for North Dakota lignite EGUs.[130] These positions have not been retracted. In addition, one additional catalyst vendor, Johnson Matthey, was willing to provide full catalyst guarantees with no stipulated need for further testing.[131] Below is Johnson Matthey's full statement:

> In March 2010, Johnson Matthey Catalysts LLC (JMC) provided budgetary prices for catalyst designs, catalyst performance guarantees, and catalyst exchange

[129] Order Denying Plaintiff's Motion to Stay and Motion for Dispute Resolution, *United States, et al.,* v. *Minnkota Power Cooperative, Inc., et al.,* United States District Court for the District of North Dakota, Southwestern Division, Civil Action No. 1:06-cv-034, Docket EPA-R08-OAR-2010-0406-0365. See pages 31-32.
[130] See our review of the June 2008 Hartenstein Catalyst Vendor Correspondence.
[131] Letter from Ken Jeffers, Johnson Matthey to Callie Videtich, dated February 27, 2012.

> schedules to Evonik Energy Services LLC (now Steag Energy Services LLC) in response to a Request for Proposal (dated February 2010) for Conceptual SCR Catalyst Design for a Low-Dust and Tail-end SCR System applied to what we understood to be an unnamed North Dakota Lignite fired power generation facility. As a quick summary, we provided catalyst designs to achieve a NOx reduction target of 90% with ammonia slip between 2 and 5 ppmvd for operating periods of 16000 to 24000 hours.
>
> With comparison to our operating experience with low-dust and tail-end SCR configurations applied to boilers/combustors firing fuels such as Powder River Basin Coal (PRB), biomass (wood, switch-grass, etc.) and municipal solid waste (MSW), and high-dust SCR experience with Texas and German lignites, JMC believes that low-dust and tail-end SCR configurations applied to North Dakota lignite fired boilers would also be technically feasible. Should other RFPs occur for specific North Dakota Lignite fired facilities, JMC would be willing to offer SCR catalyst designs with reasonable operating lifetime performance guarantees for service in a low-dust or tail-end SCR configuration.

As Johnson Matthey alludes to in its letter, it is the same vendor with recent experience in supplying catalyst to the successful SCR installations at Oak Grove Units 1 and 2 and Sandow Unit 4, which burn Texas lignite. It is interesting to note that Johnson Matthey, who received the same RFP as CERAM and Haldor Topsoe from Mr. Hartenstein, did not express any view of deceit or misrepresentation, noted by North Dakota in its handwritten CERAM and Haldor Topsoe call notes.[132] In fact, as Johnson Matthey states, it had always understood the RFP was for a North Dakota lignite EGU. Thus, the catalyst vendor with perhaps the most recent relevant experience in challenging lignite SCR experience, was willing to provide catalyst guarantees. When properly understood, the CERAM and Haldor Topsoe statement simply meant that the guarantee of LDSCR and TESCR came with context whereas the Johnson Matthey guarantee came without qualification for Milton R. Young.

3.11 April 2012 North Dakota SIP-FIP final[133]

Following the December 2011 Milton R. Young BACT Litigation, EPA concluded that due to the Court's decision and the views expressed in the BART guidelines on the relationship of BACT to BART, it would be inappropriate to proceed with its proposed disapproval of SNCR as BART and its proposed FIP to impose SCR at Milton R. Young Units 1 and 2 and Leland Olds Unit 2.[134] The comments EPA received appear to have been made under the assumption that EPA would finalize its FIP. Many of these comments concerned issues typically encountered in regional haze SIP and FIP determinations and are not covered herein. EPA stated it received many comments concerning the technical feasibility of SCR for North Dakota lignite EGUs.

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[132] See the our discussion of the CERAM and Haldor Topsoe call notes in our review of the SCR Catalyst Vendor Correspondence.

[133] Since EPA did not address comments related to feasibility, including the Sahu Nov 2011 Focused Comments, the B&McD November 2011 Comments on the proposed SIP-FIP, and the Basin Electric November 2011 Comments, we have not included them in this analysis.

[134] See EPA's final decision at 77 FR 20894 (April 6, 2012).

However, EPA explained that due to the reasoning it expressed for reversing its SCR FIP for Milton R. Young and Leland Olds—the relationship of BACT to BART—it would not address those comments.

EPA provided this statement, which we understand means that it is willing to revisit the issue of technical feasibility of SCR on North Dakota lignite EGUs:[135]

> We note, however, that the State has indicated a willingness to pursue the conduct of a pilot study at MRYS and/ or LOS to analyze the expected replacement rate of SCR catalyst exposed to flue gas from the combustion of North Dakota lignite at these cyclone units in a low-dust or tail-end configuration. It is our expectation that the results of such a study could be used to inform further evaluation of SCR as a potential control technology when the State evaluates reasonable progress in the next planning period for regional haze. This position is supported by the State's December 20, 2011 letter from North Dakota Department of Health (NDDH), L. David Glatt, to EPA, Janet McCabe.

We and EPA's own consultants have noted a number of issues related to slipstream testing that could provide false negative results. While such issues merit evaluation they do not negate the voluminous record that indicates that SCR at North Dakota lignite EGUs is indeed technically feasible.

3.12 March 2013 Proposal and February 2015 Final Reconsideration of the North Dakota SIP-FIP

In this section we review some of the key material used by EPA Region 8 to reconsider and reaffirm its April 2012 final determination that SCR was infeasible for North Dakota lignite EGUs.

EPA reaffirmed it's position, expressed in its April 2012 North Dakota SIP-FIP final decision, that due to the Court's decision and the views expressed in the BART guidelines on the relationship of BACT to BART, it would be inappropriate to proceed with its proposed disapproval of SNCR as BART and its proposed FIP to impose SCR at Milton R. Young Units 1 and 2 and Leland Olds Unit 2. EPA stated that it would not revisit comments concerning technical feasibility, but it did address a number of comments concerning other issues related to its decision making.

<u>EPA Wrongly Dismisses Vendors Willing to Provide Guarantees</u>

One commenter stated that EPA should consider the February 2012 Johnson Matthey offer of SCR catalyst designs. EPA's response is perplexing. It notes that the Johnson Matthey offer was before the Court, but it discounts it:

> And while the Johnson Matthey offer is interesting, it is hardly decisive. Considering the abundance of information that was already in the BACT record in

[135] See 77 FR 20898 (April 6, 2012).

> December 2011, it is unlikely that the court would have reached a different conclusion based only on the addition of the Johnson Matthey offer, particularly in light of the fact that two other equally reputable vendors would not provide guarantees. As noted in our BART Guidelines, "we do not consider a vendor guarantee alone to be sufficient justification that a control option will work." Id. 40 CFR part 51, appendix Y, section IV.D, step 2.

EPA only briefly summarizes the Alstom Power offer in a footnote, stating, "In our view this statement was so overlaid with conditions and qualifications that it was not unreasonable for the State to choose not to rely on it."[136] We do not see the May 30, 2007 Alstom letter as being overlaid with conditions and qualifications as EPA portrays. Regardless, Alstom did make one thing perfectly clear in the very first sentence in this letter when its stated, "[a]s Burns and McDonnell and Minnkota Power are aware, North Dakota Lignite does create many challenges for SCRs, but even with all of those challenges, it is possible to use North Dakota Lignite if the system is designed properly and Minnkota Power elects to pay for the increased capital and O&M costs associated with this fuel." Thus, there is little doubt this SCR equipment vendor thought that SCR at Milton R. Young was technically feasible. In a subsequent letter dated May 5, 2008,[137] Alstom reaffirmed its original position stating, "Alstom Power Environmental Control Systems (ECS) has reviewed the information available to us regarding SCR installations on North Dakota Lignite units and feel that our original response to Minnkota dated May 27, 2007 is still valid." Alstom noted that catalyst vendors would require a pilot test of a year, but that did not affect its firm statements that it considered SCR as being technically feasible at Milton R. Young. Thus, as we have indicated elsewhere in this document, vendors consider SCR at Milton R. Young to be feasible. No vendors have stated they consider SCR as being infeasible. Some vendors require testing, not as a test of feasibility, but in order to configure their guarantees. As EPA itself has indicated, the length of these guarantees is a cost issue.

<u>EPA's application of the Milton R. Young BACT Decision to Leland Olds is an Error</u>

In explaining its decision to apply the Milton R. Young BACT Decision to Leland Olds, EPA stated, "[w]hile LOS 2 was not the subject of the BACT determination, the same reasoning that applies to MRYS 1 and 2 also applies to LOS 2. It is the same type of boiler burning North Dakota lignite coal, and North Dakota's views regarding technical infeasibility that the U.S. District Court upheld in the MRYS BACT case apply to it as well."[138] However, as EPA noted, commenters indicated that the Leland Olds Unit 2 is significantly different from the Milton R. Young units: "these critical differences include the facts that LOS Unit 2 co-fires Powder River Basin (PRB) coal and lignite coal with lesser amounts of alleged SCR catalyst poisons; has been increasing the amount of PRB coal that it fires over time; can be modified to fire even greater quantities of PRB coal, up to 100%, completely eliminating the lignite fuel quality claims; and, unlike MRYS, is equipped with TIFI to reduce slagging and NOx emissions."

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[136] See Footnote 8 in 80 FR 8553 (February 18, 2015). SIP Appendix C.4 (EPA–R08–OAR–2010–0406–0011, pdf p. 159).
[137] *Ibid.,* pdf page 164.
[138] See 77 FR 20898 (April 6, 2012).

Yet EPA disagreed, stating, "[t]hese units have much in common. They are of the same design (cyclone firing) and similar size (in particular, MRYS Unit 2 at 517 MW and LOS Unit 2 at 440 MW). MRYS and LOS both burn primarily North Dakota lignite coal, which produces ash high in catalyst poisons (principally, sodium and potassium oxides). While MRYS burns lignite coal from the Center Mine, and LOS burns lignite coal from the Freedom Mine, these mines are located within about 40 miles of one another and produce lignite coals of similar quality."

We find EPA's arguments unpersuasive. The Court has upheld a NOx BACT determination made by North Dakota for Milton R. Young, not Leland Olds. EPA explained its arguments for extending the Court's BACT determination to BART as follows: "The first is that as part of a BART analysis, states may eliminate technically infeasible control options from further review. The second is that states generally may rely on a recent best available control technology (BACT) determination for a source for purposes of determining BART for that source."[139] In fact, neither of these arguments holds true for Leland Olds. Regarding the first, SCR has not been found to be technically infeasible by the Court for Leland Olds. Whether, as EPA assumes, the Court would have rendered the same opinion is speculation. It seems quite possible that a different record built around the Leland Olds facility, with different catalyst vendors' statements, could result in a different outcome. This is especially significant since, now knowing the focus of the Court on catalyst vendor opinions (notwithstanding its misunderstanding of them based on an inaccurate and misrepresented record), it seems likely that additional emphasis could be placed on documenting or adding to that part of the record. Regarding the second, there is no "recent [NOx] BACT determination" to use "for purposes of determining BART" for Leland Olds. We are unaware of EPA previously skipping a BART analysis of a source due to a BACT determinations from another source.

4 Presentation of New Information

Here we present an evaluation of new or otherwise overlooked and/or minimized information concerning the potential technical feasibility of the installation of SCR on North Dakota lignite EGUs. This includes information from a literature survey on such topics as SCR problems that have been overcome with other fuels (e.g., high dust lignites, high calcium coals, high sodium biomass, petroleum coke), potential catalyst deactivation and plugging, catalyst management and regeneration, foreign SCR experience with high alkali and/or alkaline earth metals fuels, and the pros/cons of various SCR arrangements (high dust, low dust, tail-end), etc. Much of the information now available reinforces information that which was available during 2007-2012 when SCR was previously (and wrongly, in our opinion) rejected as technically infeasible by North Dakota and EPA.

4.1 Low Temperature SCR Catalysts

While TESCR catalysts have been developed for at least the last three decades, that development work certainly continued in the last decade. Almost all major SCR catalyst vendors have

[139] See 80 FR 8551 (February 18, 2015).

programs for low temperature catalysts based on informal conversations. As just one example, we quote from one such study: [140]

> In recent years, great efforts have been devoted to the development of low-temperature SCR catalysts for both stationary sources and diesel engines. Mn-based catalysts have attracted great attention due to their excellent low-temperature activity. However, vulnerability to SO_2 and H_2O poisoning and preference for N_2O formation make these catalysts still far away from industrial application. V_2O_5 loaded on carbon materials has shown both high SCR activity and SO_2 tolerance at low- temperature. This type of catalyst is very promising for applications in low-temperature SCR for stationary sources.

4.2 SCR Catalyst Regeneration

Even if SCR catalysts in use lose their activity to promote the NOx to N_2 reaction due to any number of reasons, including exposure to alkali metals such as sodium or potassium that may be present such as in North Dakota lignite coals, SCR catalyst regeneration is a widely used strategy to regain some or most of the lost activity. Third party vendors have been providing this type of service for many years. Availability of regeneration means that not only can LDSCR and TESCR configurations be considered but also the more traditional high-dust or HDSCR can also be considered.

Consider one such description of regeneration below: [141]

> In this study, the waste V_2O_5–WO_3/TiO_2 denitrification catalysts from the coal-fired power plant were washed with water or nitric acid, followed by impregnating different contents of V_2O_5. The effects of the HNO_3 concentration and the additional amount of vanadium on the low-temperature selective catalytic reduction denitrification activity were investigated under the condition of high concentration of SO_2 and H_2O…The characterization results showed that nitric washing can remove most of the ammonium salts deposited on the surface of the waste catalyst and produce crystalline WO_3, which can effectively inhibit the agglomeration of vanadium species in the process of impregnation. Furthermore, it can also increase the amount of oligomeric VO_x, which can improve the denitration activity.

As another example, consider the following: [142]

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[140] Shan, W., et. al., Catalysts for the selective catalytic reduction of NO with NH at low temperature, Catal. Sci. Technol., 2015, 5, 4280-4288, https://doi.org/10.1039/C5CY00737B.

[141] Cao, Y., et. al., Regeneration of the Waste Selective Catalytic Reduction Denitrication Catalyst by Nitric Acid Washing, ACS Omega 2019, 4, 15, 16629–16637, https://doi.org/10.1021/acsomega.9b02288.

[142] Chen, Chi-Lang., et. al., Regeneration of the Deactivated SCR Catalysts, China Steel Technical Report, No. 30, pp.48－54, (2017), https://www.csc.com.tw/csc/ts/ena/pdf/no30/pages/8-Regeneration%20of%20the%20Deactivated%20SCR%20Catalysts.pdf.

> This study was for the development of the regeneration technology for the deactivated Selective Catalytic Reduction (SCR) catalysts used in the sintering plant to remove the NOx and dioxins contained in the flue gas. The optimum regeneration conditions were obtained by exploring the relationship between the regenerative process and the NOx and Dioxins removal efficiency. The regenerative process of the deactivated catalysts mainly Includes four steps: water washing, acid washing, impregnation and drying. The recovery degree of the NOx removal efficiency for the regenerated catalysts was 105% when compared with the fresh catalysts at 300°C….The NOx and dioxins removal efficiency of the regenerated catalyst was shown to reach the target values set by the Factory Acceptance Testing (FAT). Up to now, these regenerated catalysts have been continuously used for three years in the sintering plant and the measured activity is still in line with the set specifications.

Although these are just examples, there is no dispute that SCR catalyst regeneration is a mature and available commercial service that can recover most if not all of the initial catalyst activity. Costs for regeneration are properly assessed as part of the cost-effectiveness analysis for SCR. The availability of SCR catalyst regeneration further reinforces the technical feasibility of SCR for North Dakota lignite-fired EGUs..

4.3 SCR Sodium Deactivation and Regeneration

As noted earlier, one of the main perceived impediments to SCR application in North Dakota was the debate over whether alkali and/or alkaline earth metals present in the coal and in coal ash are catalyst poisons at SCR operating conditions. Minnkota and its consultants maintained that alkali and/or alkaline earth metals poisoned catalyst, while some of the vendors and EPA/DOJ consultants maintained that these constituents did not poison catalyst in all situations. For instance, see the CERAM statement on pages 12 and 58 of the May 2008 Minnkota Vendor Responses.pdf: "Sodium is not a poison to catalyst at SCR operating temperatures. Significant deactivation can occur if condensed moisture transports sodium residing at the surface into the catalyst pore structure during outage or layup." A similar HTI statement appears on page 15.

Additional discussion on this is available from recent literature. Note the finer distinction from the study below regarding the nature of the contact between alkali and/or alkaline earth metals and the catalytic surface with regards to whether or not poisoning may occur. Also note the counter-effects of tungsten and molybdenum on poisoning. [143]

> Alkali and alkaline earth metals act as effective poisons when in intimate contact with the catalytic surface…alkali metals in non-intimate contact with SCR surfaces, such as undergoing dry deposition and residency, do not appear to significantly poison catalysts…tungsten and molybdenum, ostensibly added to catalysts to moderate conversion of SO_2 to SO_3, significantly decrease poisoning of alkali metals.

[143] Baxter, L., Biomass Impacts on SCR Catalyst Performance, Technical Report, October 2005, IEA Bioenergy Task 32, Chapter 6. http://task32.ieabioenergy.com/wp-content/uploads/2017/03/Combined_Final_Report_SCR.pdf.

Recent work has also focused on mitigating potassium poisoning (in addition to sodium) on SCR catalysts. This is particularly true in biomass power plants which have been using SCR for NOx control in the US and in Europe for many years. As we have previously indicates, potassium is a stronger catalyst poison than sodium. A few strategies that can be used for addressing such poisoning based on biomass experience are as follows: [144]

> …The potassium poisoning of commercial vanadia based SCR catalysts have been studied for more than two decades…The results obtained in this work indicate that the life-time of SCR catalysts used in biomass fired power plants can be improved by ensuring a high conversion of KCl to K_2SO_4 aerosols, by reducing the operating temperature, and by increasing the size of the incoming, potassium rich aerosol particles to above 200 nm. While it may not be mechanically durable in its current state of development, applying an MgO coat to the SCR catalyst will also protect it against potassium poisoning.

As to sodium poisoning recent Chinese experience as noted below is highly instructive and indicative that SCRs can be used on coals with high sodium contents – including regeneration using not just by water washing but also by using acid solutions: [145]

> Zhundong coals have a super huge reserve and many excellent characteristics. However, the sodium content in Zhundong coal is extremely high, which can accelerate the deactivation of the V-W-TiO_2 selective catalytic reduction (SCR) catalysts. In the present work, the solution impregnation method was adopted to investigate the effect of alkali metals deposition on the SCR catalysts, while various approaches were employed to regenerate the poisoned catalysts. Experimental results indicate that sodium deposition significantly deactivates the catalytic performance of SCR catalysts and sodium hydroxide (NaOH) presents the most serious deactivation. The catalytic ability of sodium poisoned catalyst is only slightly recovered by water washing, whereas it could be improved to approach that of the fresh catalyst by acid solution washing. The regeneration effect of sulfation with SO_2 is between those of water washing and acidic solution washing. Further characterizations validated that the deactivation is mainly caused by the damage of surface acid sites. Acidic solution can remove more than 75 wt% of the deposited sodium and provide new acid sites on catalyst surface. Therefore, acidic solution washing is a satisfactory method to regenerate poisoned SCR catalysts for power plants using high sodium coals.

Another example of regeneration used specifically to deal with sodium poisoning is described below, confirming again the positive effect of acid washing: [146]

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[144] Olsen, B. K., Deactivation of SCR catalysts in biomass fired power plants, Ph.D. Thesis, Department of Chemical and Biochemical Engineering Technical University of Denmark, 2015. https://orbit.dtu.dk/files/117044428/PhD_thesis_Brian_Kj_rgaard_Olsen.pdf.

[145] Du, Y., et. al., Influence of sodium on deactivation and regeneration of SCR catalyst during utilization of Zhundong coals, https://doi.org/10.1002/apj.2031, https://onlinelibrary.wiley.com/doi/abs/10.1002/apj.2031.

[146] Zhongnan Daxue Xuebao (Ziran Kexue Ban), et. al., Sodium poisoning mechanism and regeneration of commercial De-NOx SCR catalysts, Journal of Central South University (Science and Technology) 46(6):2382-2394, June 2015, doi: 10.11817/j.issn.1672-7207.2015.06.052,

> Sodium poisoning of commercial De-NOx SCR catalysts (V_2O_5-WO_3/TiO_2) and the regeneration of deactivated catalysts by water and 0.5 mol/L H_2SO_4 were studied under simulated condition in laboratory. The physicochemical properties of catalysts were characterized by SEM, BET and XPS measurements, the reaction and deactivation mechanism of V_2O_5/TiO_2 were also analyzed and discussed. The results indicate that catalysts are poisoned seriously with low-capacity Na_2O, the catalytic activity of deactivated catalysts are recovered at varying degrees by washing with water and sulfuric acid, and the regeneration effect of washing with sulfuric acid is better than that of washing with water. Deposition of sodium salts particles and blocking of the pores and channels cause the physical poisoning of catalysts, and the main reason of chemical poisoning is attributed to the reaction of Na and V-OH to V-O-Na on the Brönsted acid sites, which results in the changes of the chemical environment of metallic oxide on the surface of catalysts, thus blocking the spread of NO and NH_3 to the inner of catalysts. The results also indicate that the denitration performance of SCR catalysts has certain positive correlation with the contents of chemical adsorbed oxygen and the ratio of w(V4+)/w(V5+) on the surface of catalysts.

4.4 Examples of Successful Biomass SCR installations

Within this report, we have noted that of the alkali metals, potassium is a more potent catalyst poison than sodium. We have also cited to sources that indicate that biomass contains a comparable amount of potassium to North Dakota lignite sodium. Despite this, there are a number of examples of successful SCR installations at EGUs that fire biomass. For instance, Johnson Matthey advertises that it has equipped hundreds of plants that burn municipal waste and biomass with SCR catalyst.[147] Regarding this, Johnson Matthey states:

> Most challenging are high-dust applications in which the raw gas exposes the catalyst to contaminants such as alkali or earth alkali metals, phosphorous or heavy metals. Depending on the plant configuration, Johnson Matthey offers high-dust SCR catalyst and low-dust SCR catalyst to achieve exceptionally low nitrogen oxide (NOx) emissions.

Babcock & Wilcox also sites to experience with SCR and biomass, particularly with LDSCR:[148]

> This low dust arrangement lessens the exposure of the catalyst to ash, which decreases the potential of plugging the catalyst, eases concerns of any unburned carbon in the ash sintering the catalyst, and mitigates catalyst deactivation due to detrimental constituents in the ash. It also allows other catalyst poisons that precipitate at lower flue gas temperatures to be collected by the particulate collection device prior to the catalyst and no longer pose a threat to deactivation

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https://www.researchgate.net/publication/282929881_Sodium_poisoning_mechanism_and_regeneration_of_commercial_De-NOx_SCR_catalysts.

[147] See https://www.jmsec.com/industries/biomass-wte/?L=0.

[148] See https://www.power-eng.com/2015/07/09/choosing-sides-benefits-of-clean-side-scr-for-biomass/.

> of the catalyst ... On a recent project that fired wood biomass, a lower sulfur fuel with relatively low variability, B&W utilized a dry sorbent injection (DSI) system in combination with the fabric filter to achieve SOx concentration in the flue gas low enough for the SCR to operate at temperatures in the range of 400-450°F.

CORMETECH also cites biomass SCR experience.[149]

The Amager Bakke waste-to-energy project in Copenhagen, Denmark has a combined power and heating capacity of 247 MW and employs a LDSCR. This plant burns municipal and biowaste.[150] The Lisbjerg, Denmark combined heat and power plant is a 110 MW unit designed for 100% straw but can co-incinerate up to approximately 50% of the heat input as wood chips. It is equipped with a tail-end SCR system.[151] The Amercentrale Unit 8, in the Netherlands, in operation since 1980 and closed in 2015, had a generating capacity of 645 MWe and a heat production capacity of 250 MW. It was a tangentially-fired PCC plant fitted with FGD and SCR, and could switch from coal, natural gas, oil or biomass[152] The Amercentrale Unit 9 is 600 MW, also fires coal and biomass and is equipped with SCR.[153]

In summary, above we present examples of recent developments specifically relating to catalyst regeneration when poisoned by alkali metals including sodium and potassium, as well as a better understanding of the mechanism(s) of such poisoning, which can be prevented by catalyst formulation changes. We also present many examples of catalyst suppliers with specific experience in biomass and municipal waste, with high levels of alkali and alkali earth metals, and plants that burn that waste and are equipped with various types of SCR systems. We conclude this real world experience represents direct evidence there is no technical impediment to the application of LDSCR and TESCR at plants burning North Dakota lignite.

5 Summary of Key Facts and Findings

Our report analyzed thousands of pages of information in an attempt to determine whether North Dakota erred when it concluded that SCR in any configuration was technically infeasible for North Dakota lignite EGUs. For the reasons summarized below, we believe that to be the case. In addition, we believe that in the interim, even more information is available to strengthen that conclusion. However, in one important way, we believe that this decision making was premised on an improper assumption—that catalyst life is a valid determinant of SCR technical feasibility. Rather, as with all SCR systems, catalyst life is a cost issue. Also misplaced is the focus on catalyst vendor guarantees as a primary determinant of technical feasibility, when in fact it should be a secondary consideration.

The misplaced threshold importance on catalyst guarantees aside, we wish to clarify the record regarding their procurement. Despite assertions to the contrary, we saw no reason to conclude

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[149] See https://www.cormetech.com/experience/.
[150] See https://www.icevirtuallibrary.com/doi/10.1680/jcien.17.00042.
[151] See https://www.cowi.com/solutions/energy/biomass-chp-in-lisbjerg-denmark.
[152] Cofiring Hgh Ratios of Biomass with Coal, Rohan Fernando, CCC/194 ISBN 978-92-9029-514-3, January 2012, IEA Clean Coal Centre.
[153] See https://www.steinmueller-babcock.com/en/references/amer-9-geertruidenberg-netherlands.html.

that the initial catalyst vendor guarantees, which were very favorable, were based on misrepresented information.

In summary, our report shows that at least TESCR and LTSCR were technically feasible for units firing North Dakota lignite coals almost a decade ago and they are definitely technically feasible options today.