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Taconite Harbor Energy Center Unit 3

Best Available Retrofit Technology (BART) Analysis For Particulate Matter

September 13, 2006

Executive Summary

Minnesota Power's Taconite Harbor Energy Center is located in Schroeder, Minnesota and consists of three75 MW (net) coal-fired units. The units have tangentially fired boilers burning low sulfur, low mercury sub-bituminous coal. Units 1 and 2 were placed in service in 1957 and Unit 3 in 1967. Consequently, Unit 3 is a BART eligible source under the Regional Haze Rule. Each unit is currently equipped with a hot-side electrostatic precipitator (ESP) for particulate emission control.

As detailed in Minnesota Power's AREA (Arrowhead Regional Emission Abatement) Plan[1,2], a multi-pollutant emission control system has been selected for implementation on all three Taconite Harbor units. The technology includes Rotating Opposed Fired Air (ROFA) and Selective Non-Catalytic Reduction (SNCR) for NOx control and a Furnace Sorbent Injection (FSI) system that injects limestone for SO_2 control. For particulate control, the existing hot-side ESPs will be retrofit for cold-side operation.

Implementation of the AREA controls will begin in late 2006, with Unit 2 scheduled as the first demonstration project of the Mobotec control technologies. Results of the demonstration project will be used in the design of the Unit 3 control system. The AREA Plan will not result in any change in output capacity or anticipated use of the three boilers. Installation of the AREA controls will result in early and voluntary compliance with future expected federal and state air quality standards. Test data for Unit 3 PM_{10} emissions will be available in 2009.

Per discussion with and guidance provided by the Minnesota Pollution Control Agency (MPCA) staff, Minnesota Power submits this particulate matter (PM) impacts analysis for its Unit 3 BART study. The results compare the visibility contributions of the proposed cold-side ESP installation and the installation of a baghouse to Pre-BART conditions. A baghouse is included in the BART analysis as a control option with slightly greater capture of filterable particulate as compared to a cold-side ESP.

Historical emissions inventories show that under normal operation, Unit 3 emits PM at around 10% of the permitted emission limit of 0.3 lb/MMBtu[3]. The existing ESP provides a great deal of control for filterable particulate emissions. For the purpose of visibility impact analyses, EPA has interpreted 'total particulate' to include both filterable and condensable particulate matter. Pre-BART modeling demonstrates that Unit 3's PM contribution to visibility impairment is negligible in comparison to the impairment attributed to sulfates and nitrates. Post-BART modeling of Unit 3 shows a 0.765 Δ-dV combined improvement in visibility for the proposed SO_2, NOx and PM control scenario. Changing from a cold-side ESP to a baghouse only results in a 0.04 Δ-dV improvement for more stringent filterable particulate controls[4]. The 0.04 Δ-dV improvement represents an insignificant reduction in visibility impairment, and for this reason, additional PM control provided by a baghouse is not warranted.

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[1] Minnesota Power's Arrowhead Regional Emission Abatement (AREA) Plan Emission Reduction Project Proposal October 13, 2005

[2] MPCA's Review of Minnesota Power's Arrowhead Regional Emission Abatement (AREA) Project January 17, 2006

[3] State standard of 0.3 lb/MMBtu is based on Method 5 filterable particulate with organic condensibles only.

[4] 98th percentile comparison of modeling results.

The relative visibility impairment contribution for different emission rate scenarios can be estimated using the CALMET, CALPUFF, and CALPOST modeling templates provided by the Minnesota Pollution Control Agency (MPCA). The Minnesota BART modeling protocol[5] describes the CALPUFF model inputs including the meteorological data set and background atmospheric ammonia and ozone concentrations along with the functions of the CALPOST post processing. There are two criteria with which to assess the expected post-BART visibility improvement: the 98th percentile delta deciview and the number of days on which a source exceeds an impairment threshold.

As defined by federal guidance[6] a source "contributes to visibility impairment” if the 98th percentile of any year’s modeling results meets or exceeds the lowest human perceptible threshold of five-tenths of a deciview (dV) at a federally protected Class I area receptor. The pre-BART evaluation of this criterion conducted by the Minnesota Pollution Control Agency identified this facility as having a BART eligible source that could cause or contribute to visibility impairment at Minnesota Class I areas. In addition to establishing whether or not a source contributes to impairment on the 98th percentile, the severity of the visibility impairment contribution or reasonably attributed visibility impairment can be gauged by assessing the number of days on which a source exceeds 0.5 dV.

CALPUFF Modeling System

The CALPUFF Modeling System is the model recommended by EPA for determining visual impacts at long distances (up to 200 kilometers) from individual emission sources. This model was used in accordance with the guidelines found in the Best Available Retrofit Technology (BART) Modeling Protocol to Determine Sources Subject-to-BART in the State of Minnesota, Final[7], with the modifications found in Appendix B.

The CALPUFF system consists of three main components (CALMET, CALPUFF and CALPOST) and a number of pre-processing programs. These pre-processing programs are designed to prepare available meteorological and geophysical data for input into CALMET. Each of these modeling components are described below:

- CALMET is a meteorological model that develops hourly wind and temperature fields on a three-dimensional gridded modeling domain. Associated two-dimensional fields such as mixing heights, terrain elevations, land use categories and dispersion properties are also included in the file produced by CALMET.
- CALPUFF is a transport and dispersion model that follows the “puffs” of material emitted from one or more sources as they travel downwind. CALPUFF simulates

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[5] MPCA, Final March 2006. *Best Available Retrofit Technology (BART) Modeling Protocol to Determine Sources Subject to BART in the State of Minnesota.*

[6] 40 CFR 51, Appendix Y.

[7] MPCA, Final March 2006. *Best Available Retrofit Technology (BART) Modeling Protocol to Determine Sources Subject to BART in the State of Minnesota.*

dispersion and chemical transformations as each puff moves away from the source, using the multi-dimensional grids generated by CALMET.

- CALPUFF produces an output file containing hourly concentrations of pollutants which are processed by CALPOST to yield estimates of ambient air extinction coefficients and related measures of visibility impairment at selected averaging times and locations.

Lambert conformal coordinates (LCC) were used in the modeling. To accommodate this coordinate system, it was necessary to use CALPUFF version 5.711a. To allow the use of larger meteorological sets and overcome other size limitations, CALPUFF was recompiled with several size parameters increased.

CALMET

Three years (2002-2004) of MM5 prognostic mesoscale meteorological data, surface weather data, precipitation data, and upper air data were used to generate the CALMET data set for use in the CALPUFF model. The CALMET computational grid was 175 grid cells (east-west) by 120 grid cells (north-south) with a grid spacing of 12 km. This grid encompasses the Taconite Harbor facility, the BWCAW and Voyageurs National Park. USGS digital elevation maps (DEMs) and land use land cover (LULC) files required by CALMET were obtained from the MPCA.

CALPUFF

CALPUFF model input files were set up for each year of CALMET data. With the exception of pollutant emission rate, model parameters were set to the values specified in the revised modeling protocol[8]. The CALPUFF modeling considered the emission of SO_2, NOx, PM_{10} (coarse particulate matter, 2.5µm to 10µm), and $PM_{2.5}$ (fine particulate matter, under 2.5µm). Emission rates and descriptions for the 6 modeled scenarios are included in Table 1.

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[8] MPCA, Final March 2006. *Best Available Retrofit Technology (BART) Modeling Protocol to Determine Sources Subject to BART in the State of Minnesota.*

Table 1 Model Scenario Descriptions

Scenario	Description			Modeled Emission Rate[9] (lb/MMBtu)			
	SO_2	NOx	PM	SO_2	NOx	PMF	PMC
1	Pre-BART	Pre-BART	Hot ESP	0.667	0.402	0.112	0.039
2	Pre-BART	Pre-BART	Cold ESP	0.667	0.402	0.089	0.031
3	Pre-BART	Pre-BART	Baghouse	0.667	0.402	0.072	0.025
4	Post-BART	Post-BART	Hot ESP	0.273	0.150	0.112	0.039
5	Post-BART	Post-BART	Cold ESP	0.273	0.150	0.089	0.031
6	Post-BART	Post-BART	Baghouse	0.273	0.150	0.072	0.025

The CALPUFF modeling also tracked SO_4, NO_3, and HNO_3, which are generated by the chemical transformation of the emitted SO_2 and NOx. The default MESOPUFF II algorithms described the rates of transformation. The MESOPUFF-generated transformation rates are a function of the background ozone and ammonia concentrations, the former set by observations, the latter using monthly average values provided by MPCA.

The CALPUFF modeling used the receptors for the Boundary Water Canoe Area Wilderness and Voyageurs National Park provided by the MPCA in the original subject-to-BART modeling files.

CALPOST

CALPOST converted the hourly concentration and monthly average relative humidity files generated by CALPUFF into 24-hour time-averaged extinction coefficients. These emissions-based extinction coefficients were compared to the 20% best days background extinction coefficients designated in the modeling protocol.

Predicting Emission Rates

Pursuant to guidance from MPCA and to be consistent with use of the highest daily emissions for pre-BART visibility impacts, the post-BART emissions to be used for the visibility impacts analysis should reflect a maximum 24-hour average basis. Estimates of the SO_2 and NOx emission rates resulting from the installation of the AREA Plan controls were used to model Post-BART control scenarios as described above in Table 1. The basis for the particulate matter emission rates is included in Table 2. PM_{10} speciation was completed using the $PM_{2.5}/PM_{10}$ ratio provided by MPCA.

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[9] A maximum heat input of 745 MMBtu/hr was used to calculate model inputs from lb/MMBtu emission rates. PM_{10} = PMC + PMF

Table 2 Particulate Emission Description

Control Option	Filterable PM Design Emissions (lb/MMBtu)	24-Hour Filterable PM Emission Rate (lb/MMBtu)	Total PM= PMF + PMC (lb/MMBtu)	Model Inputs [1]	
				PMF (lb/MMBtu)	PMC (lb/MMBtu)
Hot-side ESP (Baseline)	--	0.033 [3]	0.151 [6]	0.112	0.039
Cold-Side ESP	0.030 [2]	0.039 [4]	0.120 [7]	0.089	0.031
Baghouse	0.015 [2]	0.017 [5]	0.098 [8]	0.072	0.025

[1] Per MPCA particulate ratio, PMF= 0.26 * Total PM, and modeled PMF+PMC = Total PM
A maximum heat input of 745 MMBtu/hr was used to calculate model inputs from lb/MMBtu emission rates.
[2] Vendor specifications.
[3] May 2005 stack test data, Method 5 analysis.
[4] Increase of 30% from design basis, proposed emission limit for Unit 2 permitting.
[5] Increase of 10% from design basis.
[6] May 2005 stack test data, Filterable fraction (0.033 lb/MMBtu) + Organic and inorganic condensables (0.118 lb/MMBtu)
[7] Assumed same total PM emissions as used in Minnesota Power's permit application for Unit 2 AREA implementation. Filterable fraction (0.039 lb/MMBtu) + Estimate of organic and inorganic condensables (0.081 lb/MMBtu)
[8] Filterable fraction (0.017 lb/MMBtu) + Estimate of organic and inorganic condensables (0.081 lb/MMBtu)

The modeled emission rates illustrate that the difference in total particulate emissions between a baghouse and the cold-side ESP will be small. While the baghouse is capable of a higher emission reduction for filterable PM, total particulate will consist mainly of condensible PM. At this time, control efficiencies for condensible PM are not well understood, but it is anticipated that that degree of control will be similar between an ESP and a baghouse.

Modeled Results

Visibility impairment was modeled using the meteorological data for the years 2002, 2003 and 2004 for the predicted post-BART emission scenarios. Emissions from Unit 3 primarily impact Boundary Waters Canoe Area (BWCA). For the 3 year period modeled, Unit 3 had no days above 0.5 Δ-dV at Voyageurs National Park (VNP). For this reason, the visibility impacts analysis focuses on BWCA, but model outputs for both BWCA and VNP can be found in Appendix A. Results for the 98th percentile and number of days above 0.5 dV at BWCA are included in Table 3. The modeling results demonstrate that the addition of a baghouse for PM control provides negligible improvements in the Class 1 areas.

Table 3 Model Results for BWCA, Year 2002 through 2004

Scenario	Days Above 0.5 Δ-dV	Overall 98% Δ-dV	Speciation		
			PM	SO_2	NOx
1 (Pre-BART)	163	1.457	21.4%	34.9%	43.7%
2	154	1.421	18.0%	36.5%	45.5%
3	152	1.380	15.1%	38.0%	46.9%
4	62	0.740	39.2%	28.3%	32.5%
5 (Proposed BART)	54	0.692	34.3%	30.5%	35.1%
6	53	0.654	30.2%	32.5%	37.3%

Overall, the addition of the AREA SO_2 and NOx controls with the proposed BART PM control are predicted to reduce the number of days above 0.5 Δ-dV by 109 days over the three year modeled period and improve the 98th percentile impairment by over 50% (0.765 Δ-dV). Comparatively, Scenario 6 illustrates that the addition of a baghouse will only reduce the number of days above 0.5 Δ-dV by 1 day for the three year period and improve the 98th percentile by 0.04 Δ-dV.

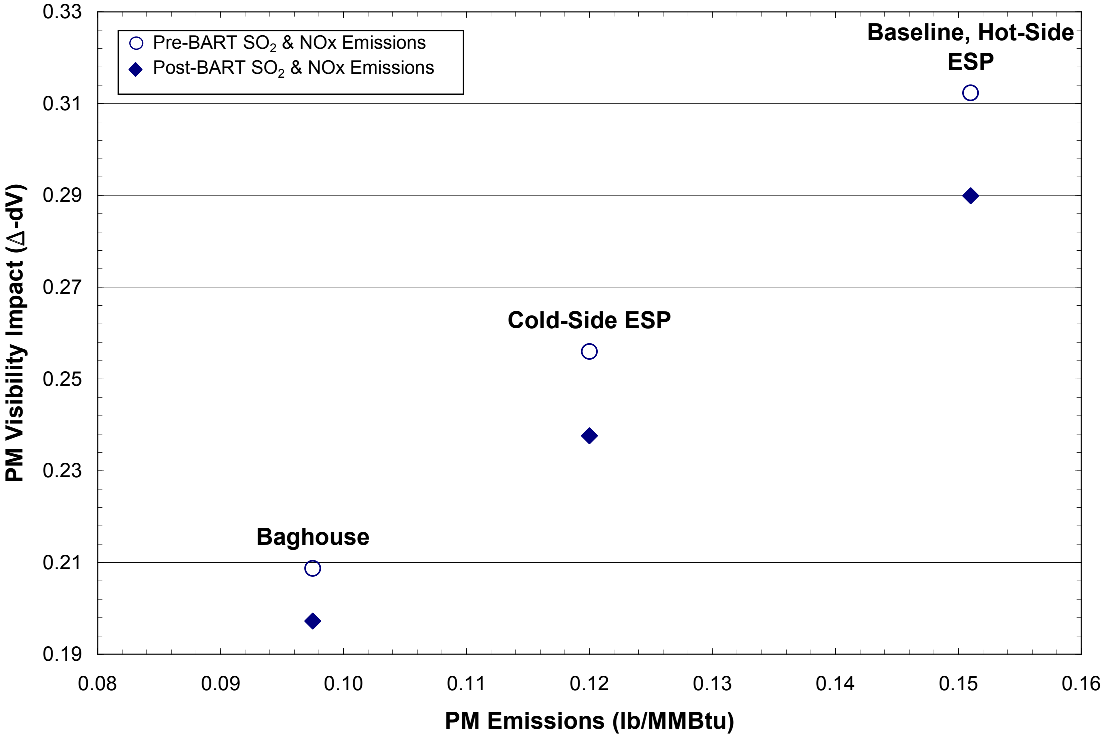

Figure 1 PM Visibility Contribution. Graphical representation of the PM contribution to visibility impairment for the 6 modeled scenarios.

Using the pollutant speciation percentages provided in Table 1, Figure 1 illustrates the particulate contribution to visibility impairment for the modeled scenarios. From this representation it is seen that as a result of pollutant interactions in the CALPUFF model, the PM contribution to visibility impairment is reduced with the addition of SO_2 and NOx controls. This figure also demonstrates the relatively small total visibility impact of particulate matter. The total range of PM contributions is on the order of 0.1 Δ-dV whereas the initial impairment contribution from Unit 3 is on the order of 1.5 Δ-dV.

Economic, Energy and Environmental Impacts

Generally, there are no significant energy or non-air quality environmental impacts that would discourage the use of an ESP or baghouse as BART. Due to the increased pressure drop requirement for a baghouse, energy use consumption would increase compared to the existing ESP. However, the cold-side ESP option will likely require energy usage comparable to the existing ESP operation. The flyash systems needed to handle the solid waste generated by particulate controls are already in place, but some modification and additional costs could be expected.

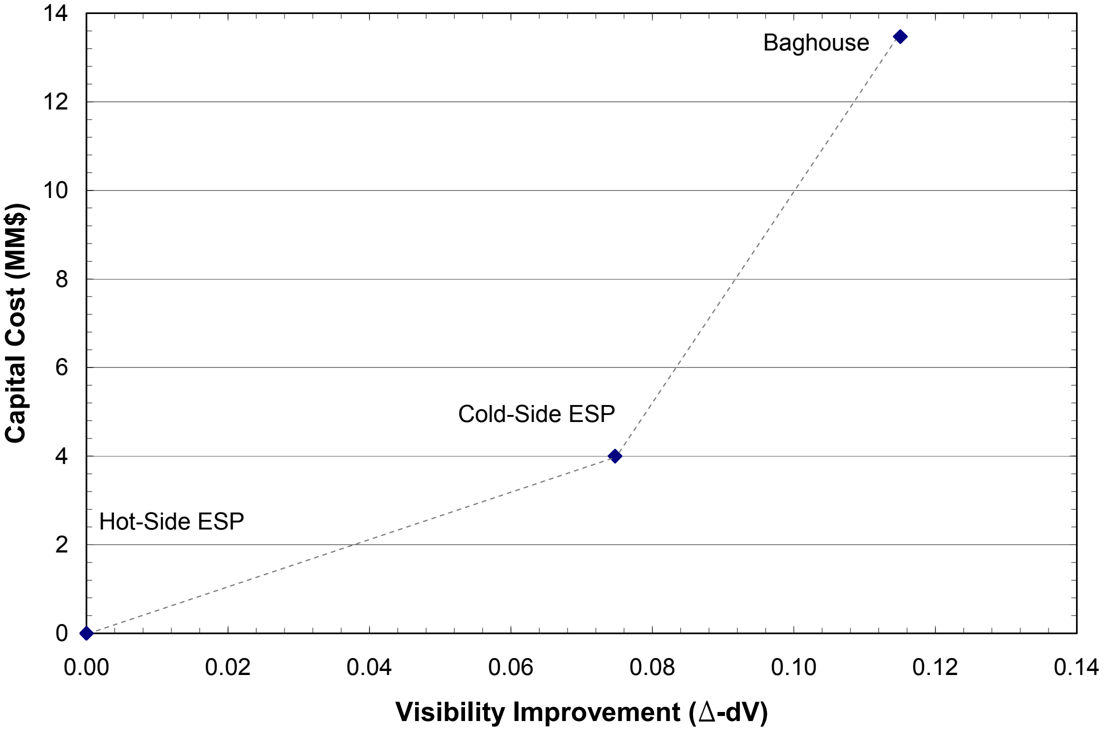

Figure 2 Incremental Cost Analysis. Comparison of attributed visibility improvement vs. capital expenditure for the Post-BART scenarios illustrates a sharp increase in the slope of the least cost envelope between the cold-side ESP and baghouse.

Figure 2 illustrates that nearly $10 million in additional capital expenditures would be needed to achieve the 0.04 Δ-dV improvement between a baghouse (not including the capital costs of site specific constraints) and the cold-side ESP. Further, Table 4 includes an approximation for the additional operating and maintenance costs associated with a baghouse.

Table 4 Control Cost Estimates[10]

Control Option	Capital Cost (MM$)	Annual O&M Cost [11]($/yr)
Cold Side ESP	4.00	-
Baghouse/ Fabric Filter	13.47	512,143

Proposed BART for PM

Through the implementation of the AREA project controls and the retrofit of the cold-side ESP, Unit 3 is expected to achieve an overall visibility reduction of 0.765 Δ-dV. This represents a 52.5% improvement from baseline conditions. Although Units 1 and 2 are not subject to BART regulations, SO_2 and NOx controls will be implemented on these units under the AREA project as well. This indicates that total visibility improvement from the Taconite Harbor facility could be as much as 3 times the improvement expected for Unit 3 alone. Minnesota Power's commitments to emission reduction under the AREA project represent a significant contribution to the default glide path for reducing impacts by 1-2% per year in Minnesota's Class I areas. A baghouse could provide a small amount of additional filterable particulate control, but would result in a negligible improvement in visibility at a significant additional cost. Further, a baghouse would involve additional energy requirements compared to an ESP. Therefore, Minnesota Power proposes a cold-side ESP retrofit as BART for Unit 3.

Implementation of the AREA Plan in scheduled to begin in late 2006. Controls for Unit 3 are currently planned for installation in late 2008. This schedule for control equipment installation is within the 5-year time-frame required for BART implementation. Stack test data will be collected from Unit 3 within one year of initial startup with the new controls. This data, in addition to any stack test information available for Units 1 and 2, will be used to better understand condensible particulate emissions from the cold-side ESP system. This information can then be used to develop a total PM_{10} emission limit that reflects the expected range of operation.

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[10] Control cost estimates per Burns and McDonnell, include as part of the cost recovery plan for the AREA project. Baghouse cost estimate is a conservative industry standard and does not include additional costs for site specific constraints.

[11] Annual O&M increase as compared to current operation.

Appendix A

Table A. Annual and Overall Modeling Results for BWCA and VNP

Scenario and Receptor	**98th percentile**					**True Maximum**				**Days Above 0.5 dV**			
	2002	**2003**	**2004**	**overall**	**limiting**	**2002**	**2003**	**2004**	**overall**	**2002**	**2003**	**2004**	**overall**
Scenario 1 BWCA	1.499	1.488	1.422	1.457	1.499	3.274	3.099	2.943	3.274	51	56	56	163
Scenario 1 Voyageurs	0.122	0.130	0.150	0.130	0.15	0.266	0.366	0.219	0.366	0	0	0	0
Scenario 2 BWCA	1.457	1.458	1.373	1.421	1.458	3.177	3.034	2.896	3.177	49	53	52	154
Scenario 2 Voyageurs	0.120	0.129	0.148	0.127	0.148	0.264	0.365	0.216	0.365	0	0	0	0
Scenario 3 BWCA	1.426	1.439	1.339	1.380	1.439	3.105	2.986	2.862	3.105	47	53	52	152
Scenario 3 Voyageurs	0.119	0.128	0.147	0.126	0.147	0.262	0.363	0.215	0.363	0	0	0	0
Scenario 4 BWCA	0.742	0.771	0.731	0.740	0.771	1.756	1.580	1.429	1.756	20	22	20	62
Scenario 4 Voyageurs	0.054	0.065	0.064	0.056	0.065	0.115	0.158	0.098	0.158	0	0	0	0
Scenario 5 BWCA	0.696	0.729	0.682	0.692	0.729	1.642	1.504	1.374	1.642	19	17	18	54
Scenario 5 Voyageurs	0.052	0.060	0.062	0.054	0.062	0.113	0.157	0.093	0.157	0	0	0	0
Scenario 6 BWCA	0.665	0.689	0.645	0.654	0.689	1.559	1.449	1.334	1.559	19	16	18	53
Scenario 6 Voyageurs	0.050	0.057	0.061	0.053	0.061	0.111	0.155	0.091	0.155	0	0	0	0