



August 22, 2011

James B. Martin, Regional Administrator  
U.S. Environmental Protection Agency, Region VIII  
1595 Wynkoop Street  
Denver, Colorado 80202-1129

**Re: Regional Haze Requirements for the Colstrip Coal-Fired Power Plant; Comments of Montana Environmental Information Center, Sierra Club, and National Parks Conservation Association**

Dear Mr. Martin:

This letter is submitted on behalf of Montana Environmental Information Center, Sierra Club, and National Parks Conservation Association in advance of our meeting with you and your staff on August 25, 2011. These comments were prepared with the assistance of Vicki Stamper, an independent air quality expert consultant, and provide our detailed recommendations for the forthcoming U.S. Environmental Protection Agency (“EPA”) rulemaking to implement regional haze requirements in Montana, and particularly, the Colstrip coal-fired power plant (“Colstrip”).

Montana Environmental Information Center, Sierra Club, and National Parks Conservation Association have thousands of members in the United States, including Montana, who are deeply committed to protecting and improving the air quality in national parks and wilderness areas in Montana and the Northern Rockies. On behalf of these members, this letter seeks to support EPA in making an adequate regional haze determination in Montana.

## **I. BACKGROUND**

The United States Congress has established a national goal for the “prevention of any future, and the remedying of any existing, impairment of visibility in the mandatory class I Federal areas which impairment results from manmade air pollution.” 42 U.S.C. § 7491(a)(1). Mandatory Class I areas include national parks and wilderness areas—the jewels of our federal public lands system. To protect these areas, a state, tribe, or EPA is required to design an implementation plan to reduce, and ultimately eliminate, haze-causing air pollution from sources that may reasonably be anticipated to cause or contribute to visibility impairment for one or more protected Class I areas located within or beyond that state’s/tribe’s boundaries. The state of Montana chose not to adopt a state haze implementation plan (SIP), and thus EPA is required to promulgate a Federal Implementation Plan (FIP) to address regional haze requirements in Montana. EPA has an unparalleled opportunity in Montana to improve regional air quality by stemming visibility-impairing emissions from the state’s oldest and most polluting facilities, particularly Colstrip.

While the Regional Haze Rule’s primary thrust is to address visibility impairments, the pollutants that cause visibility impairments are also a significant concern for public health and the economy. Because the BART Guidelines expressly require the consideration of impacts in addition to visibility, EPA must consider impacts to public health when determining BART requirements for Colstrip and other BART-eligible sources.

All of the haze pollutants at issue here— nitrogen oxides (NO<sub>x</sub>), sulfur dioxide (SO<sub>2</sub>), and particulate matter (PM)—harm public health. NO<sub>x</sub> is a precursor to ground level ozone, which is associated with respiratory disease, asthma attacks, and decreased lung function. In addition, NO<sub>x</sub> reacts with ammonia, moisture, and other compounds to form particulates that can cause and worsen respiratory diseases, aggravate heart disease, and lead to premature death.<sup>1</sup> Similarly, SO<sub>2</sub> increases asthma symptoms, leads to increased hospital visits, and can form particulates that aggravate respiratory and heart diseases and cause premature death.<sup>2</sup> PM, especially the smaller particle sizes, can penetrate deep into the lungs and cause health problems such as aggravated asthma, chronic bronchitis and heart attacks.<sup>3</sup>

EPA has estimated that by 2015, full implementation of the Regional Haze Rule nationally will prevent 1,600 premature deaths, 2,200 non-fatal heart attacks, 960 hospital admissions, and over 1 million lost school and work days.<sup>4</sup> As a result, the Regional Haze rule will result in health benefits valued at \$8.4 to \$9.8 billion annually.<sup>5</sup>

EPA must consider the environmental health impacts of haze pollution under the “non-air quality environmental impacts of compliance” best available retrofit technology (BART) consideration as it makes its determinations for the Montana haze FIP. 40 C.F.R. § 51.308 (e)(1)(A)

Colstrip—a 4 unit coal-fired power plant with a generating capacity of approximately 2,100 megawatts (MW)—is the largest source of air pollution in Montana. Units 1 and 2 became operational in 1975 and 1976, and are BART-eligible units. Units 3 and 4 obtained permits under the prevention of significant deterioration (PSD) program and became operational in 1984 and 1986, respectively. Because units 3 and 4 do not meet the definition of “existing source” (*i.e.*, were not in existence on August 7, 1977), these units are not currently considered BART-eligible under the regional haze program requirements.<sup>6</sup> However, these units are subject to

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<sup>1</sup> EPA, Health—Nitrogen Dioxide, <http://www.epa.gov/air/nitrogenoxides/health.html>

<sup>2</sup> EPA, Health—Sulfur Dioxide, <http://www.epa.gov/air/sulfurdioxide/health.html>.

<sup>3</sup> EPA, Health & Environment—Particulate Matter, <http://www.epa.gov/air/particlepollution/health.html>. See also Physicians for Social Responsibility, “Coal’s Assault on Human Health,” <http://www.psr.org/resources/coins-assault-on-human-health.html>.

<sup>4</sup> EPA, Fact Sheet—Final Clean Air Visibility Rule, [http://www.epa.gov/visibility/fs\\_2005\\_6\\_15.html](http://www.epa.gov/visibility/fs_2005_6_15.html).

<sup>5</sup> *Id.*

<sup>6</sup> See 40 C.F.R. § 51.301 and §51.308(e). We also note, however, that the issue of BART eligibility for units 3 and 4 is unclear based upon our review of the permitting and compliance history for these units.

control requirements under the reasonable progress requirements of the regional haze program. 40 C.F.R. §51.306(d)(1) and (3).

Under the regional haze program requirements, EPA is to impose emission limits reflective of BART for those BART-eligible units that are also considered subject to BART. Specifically, if a BART-eligible source may reasonably be anticipated to cause or contribute to any impairment of visibility in any mandatory Class I Federal area, then the facility is considered subject to BART. See 40 C.F.R. §51.306(e). If an existing source causes a visibility impact of 0.5 deciview or higher in a Class I area, EPA considers it contributing to visibility impairment in that Class I area<sup>7</sup>. 40 C.F.R. Part 51, Subpart Y, Section III.A.1. EPA considers a source that causes 1 deciview or higher visibility impact to “cause” visibility impairment. Id. Visibility modeling conducted on behalf of the owners of Colstrip showed that Colstrip Units 1 and 2 cause, on average, visibility impacts of 1 deciview or higher at the following Class I areas: UL Bend Wilderness, North Absaroka Wilderness, Theodore Roosevelt National Park, and the Washakie Wilderness. The units cause impacts in excess of 0.5 deciviews on average at Yellowstone National Park. See August 2007 BART Assessment Colstrip Generating Station, Appendix B at Table 5-1 (page 24). Where multiple Class I areas are impacted by a source, it is incumbent upon EPA to consider the cumulative impact of the source on all impacted Class I airsheds in evaluating Step 5 of the case-by-case BART analysis. 40 C.F.R. Part 51, Subpart Y, Section III.E.5.

The owners of Colstrip Units 1 and 2—Puget Sound Energy and PPL Montana (hereafter, “the Company”)—submitted an initial BART analysis for these units in August 2007 and submitted an addendum to the BART analysis in June 2008. As a result of these analyses, the Company concluded that BART for Colstrip Units 1 and 2 consists of the existing pollution controls with no changes. We disagree: the Company’s BART analysis provides support for a determination that additional controls and/or upgrades to controls to improve regional haze are necessary to achieve BART and meet the objectives of the regional haze program.

Colstrip Units 1 and 2 have out-of-date pollution controls. The tangentially-fired units burn subbituminous coal of 0.7% sulfur content from the northern Powder River Basin. To control NO<sub>x</sub>, the units use a low NO<sub>x</sub> concentric firing system (LNCFS) with close coupled overfire air (CCOFA) and achieve NO<sub>x</sub> emission rates in the range of 0.30 to 0.35 lb/MMBtu. See June 2008 Addendum to PPL Montana’s Colstrip BART Report at 2-1.<sup>8</sup> To control SO<sub>2</sub> and PM, the units use wet venturi particulate scrubbers; the alkalinity of the fly ash in the scrubbers helps achieve SO<sub>2</sub> removal. Id. According to the Company’s Colstrip BART report, the scrubbers remove 75-80% of SO<sub>2</sub> emissions and are designed to remove 98% of PM emissions,

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<sup>7</sup> EPA has also indicated that the threshold for determining whether a source contributes to visibility impairment in a Class I area may be lower than 0.5 deciviews, especially if numerous sources impact a Class I area. 40 C.F.R. Part 51, Subpart Y, Section III.A.1.

<sup>8</sup> Although the Company indicated in its June 2008 submission to EPA that Units 1 and 2 employ LNCFS and CCOFA to control NO<sub>x</sub> emissions, no such requirement appears in Colstrip’s Title V permit. EPA should clarify whether the Company is subject to an enforceable requirement to operate these NO<sub>x</sub> controls.

although the Company claims the scrubbers have been shown to achieve particulate control efficiencies approaching 99.5%. *Id.* The Company has indicated that these units emit SO<sub>2</sub> at 0.40 lb/MMBtu on a 30-day average basis. *Id.* at 2-3. Colstrip Units 1 and 2 typically emit filterable PM at rates of 0.05 to 0.06 lb/MMBtu, respectively. *Id.* at 2-4. These emission rates are much higher than EPA’s presumptive BART levels and do not reflect the maximum achievable emission reductions at the Colstrip units.

Colstrip Units 3 and 4 also have substandard pollution controls, especially for NO<sub>x</sub> and PM. The owners of Units 3 and 4—Puget Sound Energy, PPL Montana, PGE, Northwestern Energy, Avista, and PacifiCorp (hereafter also referred to as “the Company”)—claim the units have already met BART under the terms of the 2007 consent decree with EPA and the Northern Cheyenne Tribe. The Company did not evaluate any additional NO<sub>x</sub> controls for Colstrip Units 3 and 4 beyond those required by the 2007 consent decree. The NO<sub>x</sub> emission limits required in the consent decree are not even as stringent as the New Source Performance Standards (NSPS), let alone reflective of BART. Regardless of whether Units 3 and 4 are subject to BART,<sup>9</sup> EPA is obligated to adopt measures to achieve reasonable progress towards the national visibility goal. 40 C.F.R. §51.308(d)(1). Given that Colstrip is by far the largest emitter of regional haze impairing pollutants in the state of Montana, EPA must evaluate additional controls for Colstrip Units 3 and 4 to meet reasonable progress requirements.

In this letter, we provide our analysis of what should be required at the Colstrip units to meet BART based on the information submitted by the Company and on proposed and final BART emission limitations for other coal-fired power plants. We also provide comments on the controls that should be required at Colstrip Units 3 and 4 to meet reasonable progress requirements.

## **II. BART FOR COLSTRIP UNITS 1 AND 2**

### **A. Legal Requirements**

EPA regulations mandate that regional haze plans include emission limitations representing BART for each BART-eligible source. 40 C.F.R. §51.308(e). Best available retrofit technology or BART is defined as follows:

Best Available Retrofit Technology (BART) means an emission limitation based on the degree of reduction achievable through the application of the best system of continuous emission reduction for each pollutant which is emitted by an existing stationary facility.

40 C.F.R. § 51.301. EPA is required to determine BART for each unit on a case-by-case basis. based on a 5-factor analysis. *See id.*; *see also* 40 C.F.R. § 51.308(e)(1)(ii)(A); 42 U.S.C. § 7491. These factors are: (a) the costs of compliance; (b) the energy and non-air quality environmental impacts of compliance; (c) any existing pollution control technology in use at the source; (d) the

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<sup>9</sup> Commenters do not concede the point of inapplicability of BART to Units 3 and 4.

remaining useful life of the source; and (e) the degree of visibility improvement which may reasonably be anticipated from the use of BART. See 40 C.F.R. §§ 51.301, 51.308(e)(1)(ii)(A).

The existing pollution controls at Colstrip Units 1 and 2 are not the best systems of continuous emission reductions for the units' visibility impairing pollutant emissions (i.e., NO<sub>x</sub>, SO<sub>2</sub>, and PM). Additional, cost-effective controls are available to significantly improve visibility in the region's Class I areas.

**B. NO<sub>x</sub>**

Colstrip Units 1 and 2 are the largest emitters of NO<sub>x</sub> of any BART-eligible source in Montana by a large margin. See Summary of WRAP RMC BART Modeling for Montana, Draft #5, May 30, 2007, at Table 1 (downloaded from EPA Region VIII's website at <http://www.epa.gov/region8/air/mtregionalhaze.html>). Further, the Colstrip power plant is the largest emitter of NO<sub>x</sub> of any of the industrial facilities in Montana.<sup>10</sup> The Company's evaluation of combustion controls and post-combustion controls for NO<sub>x</sub> shows all options to be cost effective when compared to the costs required at other coal-fired electric utility units (EGUs). Nonetheless, the Company inexplicably proposed no additional controls for NO<sub>x</sub>.

1. SCR and SOFA can cost effectively achieve an adequate level of NO<sub>x</sub> control for Colstrip Units 1 and 2.

Although the Company claims that no additional NO<sub>x</sub> controls are justified, the Company's own analysis demonstrates that use of Selective Catalytic Reduction (SCR) in combination with separated overfired air (SOFA) represents the "best system of continuous emission reduction" and is cost effective. 40 C.F.R. § 51.301.

At the request of EPA, the Company evaluated a NO<sub>x</sub> emission rate of 0.06 lb/MMBtu, lower than the presumptive BART levels, through the application of SCR. The Company questioned whether such an emission rate was feasible for Colstrip Units 1 and 2, see June 2008 Addendum to PPL Montana's Colstrip BART Report at 5-4, however, the Company's analysis demonstrates that a NO<sub>x</sub> emission rate of 0.06 lb/MMBtu is readily achievable at these units with the application of SCR. To meet a 0.06 lb/MMBtu emission rate, the SCR needs to achieve 80-82% NO<sub>x</sub> removal from current NO<sub>x</sub> emission rates. SCR systems are routinely designed to achieve at least 80% removal. Further, the SCR need only achieve 68% removal if the Company also installs SOFA to reduce boiler-out NO<sub>x</sub> rates to 0.19 lb/MMBtu. Colstrip Units 1 and 2 should be able to reduce NO<sub>x</sub> to emission rates lower than 0.04 lb/MMBtu with the combination of SOFA and SCR at Colstrip Units 1 and 2.

A review of recent SCR retrofits definitively shows that very high levels of NO<sub>x</sub> removal are being achieved by recent SCR retrofit installations. NO<sub>x</sub> emission rates less than 0.05 lb/MMBtu are routinely achieved, and NO<sub>x</sub> removal efficiencies are typically around 90%.<sup>11</sup>

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<sup>10</sup> Based on emissions data available on EPA's AirData website.

<sup>11</sup> See Erickson, Clayton A. et al., Selective Catalytic Reduction System Performance and Reliability Review, The 2006 MEGA Symposium, Paper # 121, Attachment 4.

Permitting agencies have required lower NOx limits in recent BACT determinations, with many proposed and required BACT limits of 0.05-0.06 lb/MMBtu and at least one NOx BACT limit as low as 0.035 lb/MMBtu.<sup>12</sup>

There appears to be an emerging consensus within EPA that SCR generally represents BART for NOx. SCR along with combustion controls has been proposed or required as BART to meet regional haze progress goals at several coal-fired power plants elsewhere, including the Boswell Energy Center Unit 3 and Alan S. King Unit 1 in Minnesota<sup>13</sup>, Naughton Unit 3 and Jim Bridger Units 3 and 4 in Wyoming<sup>14</sup>, San Juan Units 1-4<sup>15</sup>, and Four Corners Units 1-5<sup>16</sup>. SCR along with installation of combustion controls including low NOx burners has been found to be cost effective at these units. According to data compiled by the National Park Service, the cost effectiveness of these controls ranged from \$2,258 to \$4,262/ton.<sup>17</sup> More recently, EPA determined the cost effectiveness for installation of SCR at San Juan Units 1-4 to meet a NOx emission limit of 0.05 lb/MMBtu, at between \$1,579 and \$1,920/ton of NOx removed. 76 Fed. Reg. 502 (Jan. 5, 2011).

The Company presented cost effectiveness data for installation of SCR on Colstrip Units 1 and 2 to achieve a NOx emission rate of 0.06 lb/MMBtu that shows the costs are quite reasonable. Specifically, the company projected it would cost \$1,735/ton of NOx removed to install an SCR system that would reduce current NOx emission rates of 0.35 lb/MMBtu down to 0.06 lb/MMBtu. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 5-5 to 5-6. This level of costs is within the range of BART control costs that other EGUs will have to incur under regional haze requirements, and is very similar to the costs projected by EPA to install SCR at the San Juan Units 1-4. The NOx reductions required by state regional haze plans have been projected to cost \$1,872/ton on average.<sup>18</sup>

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<sup>12</sup> The Desert Rock Energy Facility permit requires the facility to achieve, after a NOx optimization period, a NOx emission rate of 0.035 lb/MMBtu on a 365 day rolling average and an emission rate of 0.05 lb/MMBtu on a 30-day rolling average. Attachment 5. See also the National Park Service spreadsheet on BACT limits for New PC Power Plants, Attachment 6.

<sup>13</sup> See Revised Draft Regional Haze State Implementation Plan, July 2009, Minnesota Air Pollution Control Agency, at 71, available at <http://www.pca.state.mn.us/air/regionalhaze.html#sip>.

<sup>14</sup> See January 2011 Draft Wyoming State Implementation Plan Regional Haze, available at <http://deq.state.wy.us/aqd/regionalhaze.asp>.

<sup>15</sup> See 76 Fed. Reg. 504 (Jan. 5, 2004).

<sup>16</sup> See 75 Fed. Reg. 64230 (Oct. 19, 2010).

<sup>17</sup> See National Park Service Spreadsheet entitled "EGUs with proposed BART NOx Controls Mar 2011," Attachment 2.

<sup>18</sup> See id.

The Company's modeling showed almost a 1 deciview improvement in visibility with the installation of SCR and the establishment of a NO<sub>x</sub> emission limit of 0.06 lb/MMBtu at UL Bend alone. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 5-6. This is clearly a significant and perceptible improvement in visibility at this particular Class I area and the visibility improving benefits would likewise be realized at the other four Class I areas within the plant's airshed.

If SOFA was also installed, visibility improvement could be even greater without impacting cost effectiveness of the controls. Although the Company did not evaluate the installation of SOFA and SCR together, the NO<sub>x</sub> BART determination should be based on the combination of SOFA and SCR because the use of combustion controls to reduce NO<sub>x</sub> to the greatest extent followed by an SCR system represents the best continuous system of NO<sub>x</sub> emission reduction. Based on the Company's projected 0.19 lb/MMBtu NO<sub>x</sub> emission rate with the addition of SOFA, the NO<sub>x</sub> BART emission limit based on SOFA plus SCR should be 0.04 lb/MMBtu or lower. And, while the Company did not provide cost effectiveness calculations for this combination of controls, the cost per ton of NO<sub>x</sub> removed should be in the range of the \$1,735/ton that the Company estimated for SCR to meet an emission rate of 0.06 lb/MMBtu. This is because with lower NO<sub>x</sub> concentrations coming into the SCR, that will decrease both capital and operating costs of the SCR.

Based upon this information and analysis, the Company has demonstrated that installation of SCR is cost effective and will significantly improve visibility in affected Class I areas. Further, if SCR is installed along with SOFA, the cost effectiveness will improve further, and the visibility benefits in the region will be even greater. SCR with SOFA is BART for Colstrip Units 1 and 2.

2. Installation of SCR to meet BART for NO<sub>x</sub> will have other environmental benefits.

Installation of an SCR system will provide other air quality and non-air quality environmental benefits, in addition to reduction of haze-forming NO<sub>x</sub>. First, because NO<sub>x</sub> is a precursor to ozone, reductions in NO<sub>x</sub> will decrease ozone formation. Since vegetation damage has been found to occur even where ozone concentrations are below the National Ambient Air Quality Standards (NAAQS), greater reductions in NO<sub>x</sub> emissions from Colstrip as would be obtained via SOFA plus SCR could also benefit the vegetation of the region's Class I areas and areas neighboring these protected spaces.

Another issue in the region is nitrogen deposition, which is caused by wet and dry deposition of nitrates derived from NO<sub>x</sub> emissions. The significant adverse impacts of nitrogen deposition on ecological systems is well known. Critical loads (i.e., the amount of nitrogen deposition that an ecosystem can tolerate, and above which the systems become adversely impacted) are likely to soon be used to formally inform policy developments (e.g., NADP-CLAD Meeting, Pensacola, FL Spring 2009). In addition, greater reduction of NO<sub>x</sub> emissions at Colstrip would also equate with reductions in PM<sub>2.5</sub> formation.

Further, SCR systems have been shown to help oxidize mercury, which enables easier capture of mercury in downstream particulate control and sulfur dioxide scrubbers. The SCR systems could thus help Colstrip Units 1 and 2 comply with mercury emission limits.

In summary, numerous environmental benefits, in addition to the public health benefits identified above, flow from the use of SCR systems to reduce haze-forming NO<sub>x</sub> emissions, and EPA must consider these benefits in determining NO<sub>x</sub> BART for Colstrip Units 1 and 2.

### C. PM

Colstrip Units 1 and 2 are the largest emitters of PM emissions of any BART-eligible source in Montana. See Summary of WRAP RMC BART Modeling for Montana, Draft #5, May 30, 2007, at Table 1 (downloaded from EPA Region VIII's website at <http://www.epa.gov/region8/air/mtregionalhaze.html>). These units also use sub-standard control technology for particulate matter—venturi particle scrubbers. To improve visibility, EPA should consider requiring the installation of a baghouse or, as a second choice, an ESP, upstream of the existing venturi scrubber as BART at each of these units.

The EPA's BART guidelines specify that BART should be evaluated and defined for both PM<sub>10</sub> and PM<sub>2.5</sub>. See 40 C.F.R. Part 51, Appendix Y, Section IV.A. Thus, EPA must evaluate and define BART limits for both PM<sub>10</sub> and PM<sub>2.5</sub> at Colstrip Units 1 and 2. As part of the PM<sub>2.5</sub> BART determination, EPA must impose emission limits on condensable particulate matter which is typically in the size range of 2.5 microns or smaller. Alternatively, EPA could set limits on the pollutants which form condensable PM<sub>2.5</sub>, such as sulfuric acid mist and ammonia, as EPA has proposed as part of the San Juan BART rulemaking. 76 Fed. Reg. 503-4 (Jan. 5, 2011).

1. Venturi Scrubbers are not the best system of continuous emission reduction.

Venturi scrubbers are not the best system for continuous emission reduction of particulate matter. Venturi scrubbers are not typically included in best available control technology (BACT) analyses for new or modified coal-fired electric utility steam generating units. Indeed, venturi scrubbers have not been considered as BACT technology since the beginning of the prevention of significant deterioration (PSD) permitting program of the Clean Air Act because such particle scrubbers would not ensure compliance with the PM limits of the NSPS standards. Specifically, Subpart Da of the NSPS sets a PM limit for coal-fired electric utility steam generating units of 0.03 lb/MMBtu based on the use of an ESP. See 44 Fed. Reg. 33581 (June 11, 1979). Thus, venturi scrubbers could not be used for PM control at any new electrical generating units with heat input of 250 MMBtu/hr or greater that were constructed after September 18, 1978. 40 C.F.R. § 60.40Da(a)(2). Further, since BACT cannot be any less stringent than the NSPS, there could not have been any BACT determinations for coal-fired electric utility boilers that weren't based on either an ESP or a baghouse for PM control. Thus, there is no question that the venturi scrubber technology does not reflect the best system of continuous emission reduction for PM.

In its BART proposal for the Four Corners Power Plant, EPA acknowledged as much, stating that such venturi scrubbers have not been installed at coal-fired EGUs since the early 1970's because of concerns over the ability of the venturi scrubbers to continuously meet the PM standards of the 1971 New Source Performance Standard for coal-fired boilers of 0.10 lb/MMBtu. See 75 Fed. Reg. 64231 (Oct. 19, 2010). Thus, for Four Corners Units 1-3, which currently utilize venturi scrubbers for PM control, EPA proposed a significant reduction in PM emissions with a filterable PM BART emission limit of 0.012 lb/MMBtu. See 75 Fed. Reg. 64225. The Four Corners Units 1-3 currently emit filterable PM at or below 0.03 lb/MMBtu. See 75 Fed. Reg. 64231. In comparison, Colstrip Units 1 and 2 emit filterable PM at 0.047 and 0.058 lb/MMBtu, respectively, close to twice the emission rates of Four Corners Units 1-3. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 2-4 (Table 2-2).

Colstrip Units 1 and 2 emit almost five times the filterable PM emission rate achieved at coal-fired EGUs that use baghouses (i.e., 0.01 lb/MMBtu or lower). The Company has indicated that its venturi scrubbers typically remove 98% of the PM, and the filterable PM emission rates of Colstrip Units 1 and 2 are 0.047 and 0.058 lb/MMBtu, respectively. By contrast, electrostatic precipitators (ESPs) can achieve PM control efficiencies greater than 99%, whereas baghouses can achieve PM control efficiencies of 99.9% or higher.<sup>19</sup>

Baghouses have been installed since the 1970's and are the PM control technology of choice for new coal-fired EGUs because of their superior ability to control fine particulate matter. There have been several recent permits issued with BACT limits at 0.010 lb/MMBtu based on installation of a fabric filter baghouse, including the Plant Washington permit, the Longleaf permit, and the Desert Rock permit issued by EPA Region IX. See Attachments 3, 4, and 5. Yet even these recent, lower emission limits fail to reflect the low levels of filterable PM emissions that can be achieved with fabric filter baghouses. Source test data have shown that even lower levels of emissions can be achieved. As early as May 2004, at least 147 performance tests at coal-fired plants in Florida measured filterable PM/PM<sub>10</sub> at less than 0.010 lb/MMBtu and 82 recorded PM/PM<sub>10</sub> emissions at less than 0.005 lb/MMBtu. The lowest reported PM/PM<sub>10</sub> emission rate was 0.0004 lb/MMBtu.<sup>20</sup>

Further, Matt Haber, EPA Region IX's BACT expert and current Deputy Director of the Air Division, concluded in 2002 that BACT for filterable PM at two existing PC boilers firing Powder River Basin coal and equipped with a baghouse was 0.006 lb/MMBtu based on a 3-hour average and monitored via EPA Method 5 and continuously using triboelectric broken bag detectors.<sup>21</sup> Although the Colstrip Units 1 and 2 are subject to BART and not BACT, these limits reflect the best system for continuous emission reduction and thus are equally applicable under BART. Therefore, there is no reason that the Colstrip units could not achieve PM

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<sup>19</sup> See, e.g., U.S. EPA AP-42 Compilation of Emission Factors, section 1.1.4.1.

<sup>20</sup> Attachment 7, Florida Source Tests compilation.

<sup>21</sup> Attachment 8, Matt Haber, *Best Available Control Technologies for the Baldwin Generating Station, Baldwin, Illinois, Expert Report*, Prepared for the United States in connection with U.S. v. Illinois Power Company and Dynegy Midwest Generation, Inc., April 2002, p. 3.

emission rates similar to rates at new units with baghouses. Accordingly, baghouses—not venturi scrubbers—represent the best system of continuous particulate emission reduction that could be used at Colstrip Units 1 and 2.

2. The Company appears to have overestimated the costs of installing new particulate controls at Colstrip Units 1 and 2 when compared to the costs for similar controls projected in other PM BART analyses.

Recognizing that venturi scrubbers are far from the best system of continuous particulate emission reduction, the Company did evaluate the addition of an ESP or a fabric filter baghouse at Colstrip Units 1 and 2. The Company’s determination that the controls would not be cost effective likely resulted in an overestimate of costs and an underestimate of benefits from the use of an ESP or a baghouse. Specifically, the Company estimated the annualized cost of installing an ESP to meet an emission limit of 0.010 lb/MMBtu to be \$17,748.667, and the annualized cost of a baghouse to meet the same limit to be \$14,451,289. See Addendum to PPL Montana’s Colstrip BART Report, Appendix 2, Tables 6.1-2 and 6.1-4. These estimates are high in comparison to those provided in other PM BART analyses.

For example, the BART analysis for Naughton Unit 3 included an evaluation of a new full-scale fabric filter to replace an existing ESP.<sup>22</sup> Naughton Unit 3 has a heat input capacity of 3,700 MMBtu/hr and is about the size of Colstrip Units 1 and 2. The total capital cost of installing a full-scale fabric filter for this unit was projected to be \$121,000,000, and the annualized cost (assuming a 7.1% interest rate and a 20-year life) was projected to be \$12,631,543 per year.<sup>23</sup>

In addition, the BART analysis for Dave Johnston Unit 4 evaluated the replacement of a venturi particle scrubber with a new fabric filter.<sup>24</sup> Dave Johnston Unit 4 has a heat input capacity of 4,100 MMBtu/hr. The total capital cost of installing a fabric filter for this unit was projected to be \$50,073,428, and the annualized cost (assuming a 7.1% interest rate and a 20-year life) was projected to be \$6,047,573.<sup>25</sup> These units burn similar coal to that burned at Colstrip Units 1 and 2 and are similarly sized, and yet Colstrip’s cost projections for an ESP or a baghouse are inexplicably higher.

Based on this information, EPA must carefully evaluate—and commenters believe EPA should reject—the assumptions behind the Company’s ESP and baghouse cost estimates because they are higher than the projected costs for baghouses at similar EGUs and therefore suspect.

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<sup>22</sup> See Attachment 9, May 28, 2009 WY DEQ BART Application Analysis for Pacificorp Naughton Power Plant, at 18.

<sup>23</sup> Id. at 18, 21 (Tables 16 and 17).

<sup>24</sup> See Attachment 10, May 28, 2009 WY DEQ BART Application Analysis for Pacificorp Dave Johnston Power Plant, at 14.

<sup>25</sup> Id. at 17.

3. EPA should evaluate the ability to add an ESP or baghouse upstream of the particle scrubbers at Colstrip Units 1 and 2.

EPA should evaluate the option of installing new particulate controls—an ESP or a baghouse—upstream of the existing scrubber to act as the primary PM control device. It appears that the Company only evaluated the addition of an ESP or baghouse downstream of the existing particle scrubber. Specifically, the Company has stated that, because the exhaust from the venturi scrubbers is reheated above the dew point, add-on particulate controls could be feasible. See August 2007 BART Assessment Colstrip Generating Station at 4-9. With an ESP or baghouse added upstream of the scrubber, the Company could then optimize the scrubber for SO<sub>2</sub> control and likely reduce the pressure drop on the scrubber. Installation in this manner would make the baghouse or ESP the primary particulate control device.

The addition of PM controls upstream of the existing scrubber would significantly change the cost effectiveness calculations. The Company assumed that the baghouse or ESP would only remove particulate from the particulate matter emissions exiting the venturi scrubber. However, with controls upstream of the scrubber, cost effectiveness should be calculated based on the amount of PM removed from uncontrolled levels exiting the boiler—i.e., from 0% control to 99+% control—rather than based on the incremental benefit of additional PM control beyond what the particle scrubber achieves.

Installation of a baghouse or ESP before the flue gas stream even reaches the venturi scrubber would be cost-effective for Colstrip Units 1 and 2. To determine the amount of particulate matter that will be reduced with an ESP or a baghouse installed upstream of the scrubber, one must estimate the PM emission rate exiting the boiler, which in turn requires knowing the ash and heat value of the coal burned at Colstrip Units 1 and 2. It does not appear that the Company submitted such info to EPA. However, information from the United States Geological Survey for the Colstrip coal mining area permits us to venture a reliable estimate of uncontrolled PM emissions from the Colstrip plant. Specifically, it appears that the Colstrip Units burn Rosebud mine coal, which has an average ash content of 8.24% and an average heating value of 8,767 Btu/lb.<sup>26</sup> Assuming that 80% of the ash is emitted as flyash, that means the uncontrolled PM exiting Colstrip's Unit 1 and 2 boilers is emitted at a rate of approximately 7.52 lb/MMBtu.

If controlled filterable PM emissions are assumed to be 0.010 lb/MMBtu (the emission rate that EPA requested the Company to use as a basis for evaluation), then the reduction in PM emissions from an ESP or baghouse installed upstream of the scrubber should be based on the product of: 1) the annual average heat input to Colstrip Units 1 and 2, and 2) the difference in the uncontrolled and controlled PM emission factor. The average annual heat input over 2001-2003 (i.e., the same years the Company used for defining base case) was 27,408,013 MMBtu for

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<sup>26</sup> See Chapter PC, Colstrip Coalfield, Powder River Basin, Montana: Geology, Coal Quality, and Coal Resources, in U.S. Geological Survey Professional Paper 1625-1 at PC-2 and PC-7 (available at <http://pubs.usgs.gov/pp/p1625a/Chapters/PC.pdf>).

Colstrip Unit 1 and 27,548,547 MMBtu for Colstrip Unit 2.<sup>27</sup> Based on this annual heat input data, a filterable PM emission limit of 0.010 lb/MMBtu would equate to approximately 103,000 tons of filterable PM reduced each year at each unit. Using the Company's annualized cost estimates of \$17,748,667 for an ESP and \$14,451,289 for a baghouse, the cost effectiveness of installing either of these controls upstream of the scrubber would be \$172/ton for an ESP and \$140/ton for a baghouse. These more realistic cost effectiveness numbers show that installing an ESP or a baghouse upstream of the scrubbers at Colstrip Units 1 and 2 would be extremely cost effective with the baghouse being the more cost effective option. As discussed below, a baghouse will provide greater environmental benefits than an ESP. Thus, a baghouse is plainly the control technology of choice for PM BART at Colstrip.

4. Installation of a baghouse to meet a PM emission limit of 0.010 lb/MMBtu will improve visibility.

Installation of a baghouse or an ESP would improve visibility. Modeling conducted by the Company for installation of a baghouse or an ESP to meet a filterable PM emission rate of 0.010 lb/MMBtu demonstrated that such PM reductions would decrease visibility impairment by 0.048 deciviews. See June 2008 Addendum to PPL Montana's Colstrip BART Report at ES-6. The Company determined that the visibility improvement would not be discernable and thus that installation of PM controls is not warranted. Id. at ES-3.

However, the Company did not model the installation of an ESP or a baghouse upstream of the scrubber. With this arrangement, the scrubber could be optimized for SO<sub>2</sub> control, thereby greatly reducing visibility-impairing SO<sub>2</sub>. Thus, the visibility benefits of the reductions in PM should be evaluated in combination with the benefits of upgrading and optimizing the scrubber for higher levels of SO<sub>2</sub> removal.

In addition, EPA should evaluate whether the existing particle scrubbers at Colstrip Units 1 and 2 are causing localized visibility impacts. EPA Region IX has noted that the existing venturi scrubbers at Four Corners Units 1-3 cause a secondary plume that is formed in the steam plume and that can be seen for quite some distance from the Four Corners Power Plant.<sup>28</sup> According to EPA, the use of a venturi scrubber at these units causes visibility impairment in the region around the plant. EPA states that the secondary plume formed at Four Corners Units 1-3 could likely be due to the poor control of fine particles.<sup>29</sup> It is very plausible that the same problems occur with the use of a venturi scrubber at Colstrip Units 1 and 2.

The installation of a baghouse upstream of the venturi scrubber could alleviate any problems with secondary plumes. Again, a baghouse is the superior PM technology for

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<sup>27</sup> Based on data available on EPA's Clean Air Markets Database.

<sup>28</sup> EPA's Technical Support Document, Proposed Rule: Source Specific Federal Implementation Plan for Implementing Best Available Retrofit Technology at Four Corners Power Plant: Navajo Nation, at 81. (Attachment 11).

<sup>29</sup> Id.

removing fine particulate matter. The filtration media determines the control efficiency of a baghouse for very small particles. Filtration media are available that allow 99.99% of the PM<sub>2.5</sub> fraction to be removed. These include Daikin's AMIREX™, PTFE membrane filters<sup>30</sup> and W.L. Gore's L3650.<sup>31</sup> See summary of U.S. EPA's ETV test results in Attachment 10.<sup>32</sup> A bag leak detection system also greatly helps in reducing and eliminating spikes in PM emissions. Thus, if the venturi scrubbers at Colstrip Units 1 and 2 cause a secondary plume problem as occurs at Four Corners Units 1-3, the installation of a baghouse upstream of the scrubber to serve as the primary particulate control device could help address this issue.

Further, as discussed above, use of a baghouse at Units 1 and 2 will likely reduce PM emissions lower than 0.010 lb/MMBtu. The Company's modeling of a filterable PM emission rate of 0.010 lb/MMBtu does not reflect the lower emission rates which will likely occur with the use of a baghouse.

For all of these reasons, in determining whether it is appropriate to require new PM controls to meet BART, EPA cannot and should not rely on the Company's modeling, which is based only on lowering the PM emission rate to 0.010 lb/MMBtu. The installation of a baghouse upstream of the existing venturi scrubber would likely have myriad benefits for visibility that go beyond attainment of a 0.010 lb/MMBtu emission limit. The visibility impacts analysis for PM BART must consider all of the benefits that could be obtained from replacing the particle scrubber with an ESP or, preferably, a baghouse, and then optimizing the scrubber for SO<sub>2</sub> removal.

5. The energy and environmental impacts analyses weigh strongly in favor of installation of baghouses at Colstrip Units 1 and 2.

Additional air-quality related factors support additional PM controls for Colstrip Units 1 and 2.

- a. A baghouse will result in the greatest reduction in mercury emissions and is likely necessary to meet mercury limits.

It is very likely that a baghouse will be required to meet either Montana limits or the forthcoming maximum achievable control technology (MACT) standards for existing electrical generating steam generating units (EGUs). In May 2011, EPA published its proposed EGU

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<sup>30</sup> McIlvaine Hot Topic Hour, Filter Media Selection for Coal-Fired Boilers, September 13, 2007, Presentation by Todd Brown, Daikin America, Inc. Attachment 12. Voice recording available online to subscribers of McIlvaine Power Plant Knowledge System and available for purchase.

<sup>31</sup> USEPA, ETV Joint Verification Statement, Baghouse Filtration Products, W.L. Gore & Associates, L3650, Attachment 13 (<http://epa.gov/etv/pubs/600etv06042s.pdf>).

<sup>32</sup> Fabric Filtration Media are certified by the U.S. EPA Environmental Technology Verification Program using the "Generic Verification Protocol for Baghouse Filtration Products" to Achieve 99.99% Removal of PM<sub>2.5</sub>.

MACT standards, which will make the Colstrip units subject to a mercury emission limit of 1.2 lb/TBtu.<sup>33</sup>

It is well known that coal-fired boilers equipped with baghouses achieve better control of mercury than those equipped with ESPs. Mercury control at bituminous coal-fired boilers with a cold-side ESP and a wet scrubber averaged 81% as compared to 98% control achieved with a baghouse and wet scrubber.<sup>34</sup> And boilers equipped with baghouses that use carbon injection can achieve higher levels of mercury control with a lower carbon injection rate as compared to boilers equipped only with ESPs.<sup>35</sup>

When coal is burned in a boiler, the mercury in the coal is volatilized and converted to elemental mercury vapor ( $Hg^0$ ).  $Hg^0$  is insoluble in water and therefore must be adsorbed by a sorbent or converted to a soluble form so it can be captured in a wet scrubber or another particulate control device such as a baghouse. According to EPA, the form of mercury most easily removed is  $HgCl_2$  and the formation of this compound is dependent on how much chlorine is in the coal – less chlorine equates to less formation of  $HgCl_2$ .<sup>36</sup> Thus, EGUs that burn eastern bituminous coal with high chlorine levels often achieve high levels of mercury control via existing  $SO_2$  scrubbers and PM controls, while EGUs burning low chlorine coal, such as the northern Powder River Basin subbituminous coal used at Colstrip, often achieve lower control of mercury via the  $SO_2$  and PM controls.

Compared to a particle scrubber or a dry ESP, a fabric filter baghouse provides additional opportunities for the mercury to adhere to the unburned carbon particles in the fly ash as the flue gas moves through the filter cake on the bags. Activated carbon, a sorbent which adsorbs mercury, is typically much more effective when a baghouse rather than an ESP is used, because the activated carbon becomes part of the filter cake.<sup>37</sup> Thus, vendors have developed the Toxecon pollution control scheme to assist with mercury removal at units with existing ESPs, which involves adding a downstream polishing baghouse (or integrating a baghouse with the ESP) along with activated carbon injection to improve mercury removal.

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<sup>33</sup> 76 Fed. Reg. 24976 (May 3, 2011). See also May 18, 2011 Memo with Subject “National Emission Standards for Hazardous Air Pollutants (NESHAP) Maximum Achievable Control Technology (MACT) Floor Analysis for Coal- and Oil-Fired Electric Utility Steam Generating Units – REVISED,” available at <http://www.epa.gov/ttn/atw/utility/utilitypg.html>, in which EPA revised the existing EGU MACT floor determination from 1.0 lb/TBtu to 1.2 lb/TBtu.

<sup>34</sup> See Attachment 14, US EPA, Performance and Cost of Mercury and Multi-Pollutant Emission Control Technology Applications on Electric Utility Boilers, EPA-600/R03-110 (Oct. 2003) at 7.

<sup>35</sup> See, e.g., [http://hamon-researchcottrell.com/tech\\_ff](http://hamon-researchcottrell.com/tech_ff).

<sup>36</sup> See Attachment 14, US EPA, Performance and Cost of Mercury and Multi-Pollutant Emission Control Technology Applications on Electric Utility Boilers, EPA-600/R03-110 (Oct. 2003) at 5.

<sup>37</sup> *Id.* at 8-9.

Therefore, use of a fabric filter baghouse at Colstrip Units 1 and 2 will not only greatly reduce particulate, but will also provide for the greatest control of mercury pollution from these units.

The greater reductions in mercury achievable with installation of baghouses at Colstrip Units 1 and 2 could help address mercury deposition levels in eastern Montana. Studies sponsored by EPA demonstrate that up to 70 percent of local deposition of mercury from power plants and industrial sources can be linked to local sources during wet deposition events.<sup>38</sup> Fish consumption advisories due to mercury contamination have been issued for Castlerock Lake in the vicinity of Colstrip as well as for the Bighorn reservoir in southeastern Montana.<sup>39</sup> The installation of baghouses to meet BART for PM at Colstrip Units 1 and 2 thus could reduce the levels mercury deposited in the region from these units.

- b. New PM controls will be needed to meet EPA's proposed PM limit for non-mercury metal HAPs.

Updated PM controls will also be necessary at Colstrip Units 1 and 2 to meet EPA's proposed PM limit for non-mercury metal HAPs. Specifically, EPA has proposed a PM limit of 0.03 lb/MMBtu as a surrogate for non-mercury metal hazardous air pollutants (HAPs). EPA's proposed limit is a limit on total particulate matter (filterable plus condensable PM). Colstrip Units 1 and 2 already emit filterable PM at rates close to twice that of the EPA's proposed 0.03 lb/MMBtu total PM limit (at 0.047 and 0.058 lb/MMBtu, respectively<sup>40</sup>). Consequently, improved PM controls (and also likely improved SO<sub>2</sub> controls to reduce condensable PM) will be necessary for Colstrip Units 1 and 2 to meet a total PM MACT limit of 0.03 lb/MMBtu. As previously stated, a baghouse is typically more effective in removing PM than an ESP. This is especially true for fine particulate matter.<sup>41</sup> In evaluating BACT for Desert Rock, EPA Region 9 stated that baghouses are the top-rated control technology and that ESPs are not considered the top-rated PM control because they do not control fine particulate as well as baghouses and because they are not generally capable of additional control of other pollutants such as acid gases and mercury.<sup>42</sup>

Not only can a baghouse achieve lower filterable PM emission rates, but a baghouse also removes more sulfuric acid mist which is a condensable particulate. According to EPRI's "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," a cold-side ESP for a

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<sup>38</sup> Gerald Keeler, Matthew Landis, *et al.*, Sources of Mercury Wet Deposition in Eastern Ohio, USA, 40 *Envtl. Sci. & Tech.* 5874-5881 (Sept. 2006).

<sup>39</sup> See EPA's National Listing of Fish Consumption Advisories at <http://oaspub.epa.gov/nlfa/nlfa.advrpt>.

<sup>40</sup> See June 2008 Addendum to PPL Montana's Colstrip BART Report at 2-4 (Table 2-2).

<sup>41</sup> See, e.g., the Institute of Clean Air Companies' information on particulate controls at <http://www.icac.com/i4a/pages/index.cfm?pageid=3398>.

<sup>42</sup> See US EPA Region 9, Ambient Air Impact Report for Desert Rock Energy Project at 26. (Attachment 15).

plant burning subbituminous coal will remove approximately 38% of the sulfuric acid mist while a baghouse will remove 90%.<sup>43</sup>

Furthermore, the BACT limits for fluorides, another condensable particulate, are typically the lowest at units that use baghouses along with wet scrubbers. In addition, baghouses provide improved control of fine particulates (i.e., PM<sub>2.5</sub>) as compared to ESPs, as discussed above.

In addition, if a baghouse was installed upstream of the scrubbers at Colstrip Units 1 and 2, then the scrubber could be more readily optimized for SO<sub>2</sub> removal which would then result in significant reductions in condensable PM emissions.

New PM controls will be required to meet the PM limit of the proposed EGU MACT rule, and a baghouse will likely be the control technology needed to meet the total PM limit of 0.03 lb/MMBtu. A baghouse has superior ability to remove sulfuric acid mist, fluorides, and fine particulate matter, and its use allows the scrubber to be optimized for SO<sub>2</sub> control. In its regulatory impact analysis for the proposed EGU MACT rule, EPA assumed that many EGUs would need to be retrofitted with baghouses to meet the total PM limit.<sup>44</sup> And, it must be noted that the compliance timeframe of the EGU MACT rule will be similar to that for BART. Specifically, under a consent decree, EPA is required to finalize its EGU MACT rule by November 16, 2011. Under the proposed MACT rule (and as required by the Clean Air Act), existing sources will be required to comply with the MACT rule within three years of promulgation – or by approximately the end of 2014. The Company has a similar timeframe in which to meet BART requirements. These other requirements should be taken into account in evaluating BART for PM at Colstrip Units 1 and 2.

In sum, installation of new PM control devices at Colstrip Units 1 and 2 is necessary and justified under the BART requirements of the regional haze rule. Installation of a baghouse or an ESP upstream of the scrubber at each Colstrip unit is very cost effective, with installation of a baghouse being the most cost effective at \$140/ton compared to \$172/ton for an ESP. A baghouse is a superior particulate control device to an ESP because it is the best system of continuous PM emission reduction, and a baghouse provides better ability to control fine particulate matter and acid gases. Further, the installation of a baghouse typically provides for much higher mercury removal than an ESP. Thus, installation of baghouses at Colstrip Units 1 and 2 will very likely be required to meet MACT. Installing a baghouse upstream of the existing scrubbers will allow the company to upgrade and optimize the scrubber for improved SO<sub>2</sub> removal, which will result in significant benefits to visibility (discussed further in the SO<sub>2</sub> comments of this letter).

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<sup>43</sup> See Attachment 16, EPRI's "Estimating Total Sulfuric Acid Emissions from Stationary Power Plants," Version 2010a, Table 4-4 at 4-20. The F<sub>2</sub> factors in the table represent the fraction of SAM in the flue gas after the ESP or baghouse, so the percent removal can be determined by subtracting the F<sub>2</sub> factors from 1.

<sup>44</sup> See Attachment 17, EPA, Regulatory Impact Analysis of the Proposed Toxics Rule: Final Report, March 2011, at 8-5, and also at 7-8.

## D. SO<sub>2</sub>

Existing SO<sub>2</sub> controls for Colstrip Units 1 and 2 are also sub-standard. According to the Company, these units are currently removing approximately 75% SO<sub>2</sub> emissions with the existing venturi scrubbers and the units' SO<sub>2</sub> emission rates are typically 0.40 lb/MMBtu on a 30-day rolling average. See August 2007 BART Assessment Colstrip Generating Station at 4-15 to 4-16. This level of SO<sub>2</sub> control fails to reflect the best system of continuous SO<sub>2</sub> emission reduction that can be achieved at the Colstrip Units 1 and 2. Additional SO<sub>2</sub> controls—e.g., the addition of a lime-injection system, scrubber upgrades, or scrubber replacements—would improve visibility and are cost effective.

1. The existing scrubbers are not the best system of continuous SO<sub>2</sub> emission reduction

According to the available information on the coal used at Colstrip, it appears that the Company overstated the SO<sub>2</sub> removal efficiency being achieved with the venturi scrubbers at Colstrip Units 1 and 2. The Company has indicated that the Powder River Basin coal burned at Colstrip has a sulfur content of 0.7%. See Addendum to Montana PPL's Colstrip BART Report at 2-1. According to data in a USGS Report, Rosebud mine coal, which Colstrip burns, has an average sulfur content of 0.65% and an average heating value of 8,767 Btu/lb.<sup>45</sup> This means that the average uncontrolled SO<sub>2</sub> emissions based on sulfur in the coal range from 1.5 to 1.6 lb/MMBtu. However, this does not reflect the amount of SO<sub>2</sub> going to the scrubber, as some of the sulfur in the coal falls out in the bottom ash of the boiler. According to EPA, "[o]n average, about 95 percent of the sulfur present in bituminous coal will be emitted as gaseous SO<sub>x</sub>, whereas somewhat less will be emitted when subbituminous coal is fired."<sup>46</sup> Using EPA's AP-42 emission factors for subbituminous coal-fired boilers like Colstrip Units 1 and 2, the range of uncontrolled SO<sub>2</sub> emissions exiting the boiler, based on coal with sulfur content of 0.65%-0.70% and heat value of 8,767 Btu/lb, are 1.30 to 1.40 lb/MMBtu.<sup>47</sup> Based on this range, the existing scrubbers at Colstrip Units 1 and 2 are only achieving 69 to 71% SO<sub>2</sub> removal on average—not the 75-80% control stated by the Company. This is a substandard level of SO<sub>2</sub> removal for a coal-fired boiler and fails to reflect the best system of continuous SO<sub>2</sub> emission reductions that could be achieved at Colstrip Units 1 and 2.

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<sup>45</sup> See Chapter PC, Colstrip Coalfield, Powder River Basin, Montana: Geology, Coal Quality, and Coal Resources, in U.S. Geological Survey Professional Paper 1625-1 at PC-2 and PC-7 (available at <http://pubs.usgs.gov/pp/p1625a/Chapters/PC.pdf>).

<sup>46</sup> See EPA's AP-42, Chapter 1.1 Bituminous and Subbituminous Coal Combustion, at 1.1-3.

<sup>47</sup> See AP-42, Table 1.1-3, SO<sub>2</sub> emission factor in lb/ton of coal burned of 35 x sulfur content for tangentially-fired subbituminous coal-fired units.

2. Scrubber upgrades should be required to achieve lower SO2 limits.

Based on the Company's supplemental BART analysis, the SO2 removal efficiency of the existing scrubbers at Colstrip Units 1 and 2 could be improved with the injection of lime or limestone, the sorbents typically used for SO2 control in scrubbers. The Colstrip scrubbers achieve approximately 70% SO2 removal from the alkalinity of the fly ash in the flue gas. The BART Guidelines require evaluation of scrubber upgrades

Evaluation of the installation of a lime injection system falls squarely under the BART Guidelines' direction to evaluate options that would "improve the system's overall removal efficiency." 40 C.F.R. Part 51, Subpart Y, Section IV.E.4. There is no basis for the Company's claim that the BART guidelines do not require evaluation of adding a lime injection system to a scrubber that is achieving at least 50% SO2 removal.

The Company has expressed concerns with lime injection that, due to lime scaling and the fact that the scrubber has no spare scrubber module, the scrubber module will need to be taken off line more frequently for maintenance. See, e.g., June 2008 Addendum to PPL Montana's Colstrip BART Report at ES-2. While scaling is a concern with any lime or limestone based wet scrubber, and techniques are available to deal with this issue, one option to deal with this issue is the use of magnesium-enhanced lime. Magnesium enhanced lime has been used in FGD systems since the 1970's, and it has been capable of high SO2 removal with little scaling, thus providing for a high availability.<sup>48</sup> According to vendor literature on this technology, magnesium-enhanced lime scrubbers are capable of very high SO2 removal efficiencies in excess of 95%.<sup>49</sup> It is further significant that Reid Gardner Units 1-3 do not have spare absorber modules, and these units will be subject to a 0.15 lb/MMBtu SO2 BART limit (and are emitting SO2 well below that limit) as discussed above.<sup>50</sup>

Additional upgrades to the scrubbers beyond the addition of lime injection could be made to further improve SO2 removal. Those upgrades could include a redesign of the spray headers or nozzle configuration, improvements to scrubber auxiliary system equipment, other physical changes to improve liquid-to-gas contact, and changes in scrubber chemistry to improve SO2 removal. Other changes include improving gas flow distribution through ductwork changes, improving spray level coverage, adding frothing trays, increasing liquid to gas ratio (increasing recycle flow), and injecting dibasic acid.<sup>51</sup> While the Company purportedly considered some

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<sup>48</sup> See Roden, Bob et al., New Magnesium-Enhanced Lime FGD Process, Carmeuse-North America Technology Center, Pittsburgh, PA (Attachment 22).

<sup>49</sup> Id.; see also Nolan, Paul S., Babcock & Wilcox Co., Flue Gas Desulfurization Technologies for Coal-Fired Power Plants, presented at Coal-Tech 2000 International Conference, November 13-14, 2000, Jakarta, Indonesia, at 3. Attachment 23.

<sup>50</sup> See Weilert, Carl & Emily Meyer, Burns & McDonnell, Utility FGD Design Trends at 22 (Attachment 29).

<sup>51</sup> See Carstens, Andrew J. et al., Performance Upgrades for Low-Sulfur Wet Scrubbers, Sargent & Lundy and CPS Energy, Paper # 134, at 6-12 (Attachment 30).

scrubber changes such as installation of liquid distribution rings and installation of perforated trays, there are numerous other options that should have been considered to improve liquid to gas contact in the scrubber. If an ESP or baghouse was installed upstream of the scrubber and the scrubber was no longer the primary PM control device, physical design changes could be made that could then improve the SO<sub>2</sub> removal efficiency and operating parameters of the scrubber. For example, at the Reid Gardner units, the venturi section will be opened up to improve draft flow. If that was done at the Colstrip scrubbers, it could allow for installation of additional trays or physical changes to improve scrubber to gas contact which would improve overall efficiency.

Lower SO<sub>2</sub> limits should be achievable with scrubber upgrades. The Company only evaluated reducing SO<sub>2</sub> to an emission rate of 0.15 lb/MMBtu in evaluating SO<sub>2</sub> BART. However, based on review of the SO<sub>2</sub> emission rates achieved at Colstrip Units 3 and 4 as well as the Reid Gardner units, Colstrip Units 1 and 2 should be able to achieve even lower SO<sub>2</sub> emission rates with upgrades to the scrubbers.

Colstrip Units 3 and 4 have particle/SO<sub>2</sub> scrubbers that rely on fly ash and lime injection. According to the company, these units achieve 95% SO<sub>2</sub> control and SO<sub>2</sub> emission rates of 0.08 lb/MMBtu. See January 31, 2011 submittal to EPA from PPL Montana regarding Colstrip Units 3 and 4, Ex. 2 at 2. The Reid Gardner units have installed baghouses upstream of their existing particle/SO<sub>2</sub> scrubber and also have average SO<sub>2</sub> emission rates of 0.08 lb/MMBtu or less.<sup>52</sup> As previously stated, the Reid Gardner units do not have spare scrubber modules, although Colstrip Units 3 and 4 do. Based on the available info for these similar units, Colstrip Units 1 and 2 should be able to achieve SO<sub>2</sub> emission rates much lower than 0.15 lb/MMBtu.

Even if the Company claims a spare scrubber module would be needed to consistently achieve lower SO<sub>2</sub> emission rates, it must be noted that EPA's BART guidelines specifically provide for the evaluation of options to improve scrubber availability including by "increasing auxiliary equipment redundancy." 40 C.F.R. Part 51, Appendix Y, Section IV.E.4. Thus, it is entirely appropriate and required under the EPA's BART guidelines to evaluate the installation of a spare scrubber module to meet lower SO<sub>2</sub> emission limits as BART. Given that a 0.15 lb/MMBtu emission limit only reflects 89% SO<sub>2</sub> removal across the scrubber, the Company must be required to evaluate all options that would enable the Colstrip units to achieve the best continuous level of SO<sub>2</sub> emission reductions as BART. EPA should consider scrubber upgrades, including the addition of a the lime injection system, for lowering SO<sub>2</sub> emissions from Colstrip Units 1 and 2.

3. The Company has demonstrated that scrubber upgrades to meet SO<sub>2</sub> BART are extremely cost effective.

As the Company demonstrated, it is very cost effective to add a lime injection system to improve SO<sub>2</sub> control at Colstrip Units 1 and 2 to meet an SO<sub>2</sub> emission limit of 0.15 lb/MMBtu. The Company determined that with a lime injection system, it could continually meet an SO<sub>2</sub>

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<sup>52</sup> See Attachment 19.

emission limit of 0.15 lb/MMBtu<sup>53</sup> at a cost of \$486/ton of SO<sub>2</sub> removed. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 4-1 to 4-2. This is well under the median cost per ton for SO<sub>2</sub> controls that have been required as BART as part of state regional haze plans. Specifically, the median cost of SO<sub>2</sub> controls to meet BART is \$1,571/ton of SO<sub>2</sub> removed and the average cost is \$1,967/ton of SO<sub>2</sub> removed. See National Park Service's spreadsheet entitled "EGUs with Proposed BART SO<sub>2</sub> Controls," Attachment 18. EPA recently proposed to require several EGUs in Oklahoma to install new SO<sub>2</sub> controls to meet a BART emission limit of 0.06 lb/MMBtu, finding new controls to be cost effective at costs ranging from \$1,291 to \$2,366 per ton of SO<sub>2</sub> removed. 76 Fed. Reg. 16183 (Mar. 22, 2011) (tables 4 and 6). The Company's projected costs to upgrade the scrubbers at Colstrip Units 1 and 2 of \$486/ton of SO<sub>2</sub> removed are quite reasonable when compared to the costs other EGUs have to incur to meet BART.

Upgrades to the current scrubbers are well-justified even if the Company installs PM controls upstream. If an ESP or baghouse was installed upstream of the scrubber, then the amount of fly ash entering the wet scrubber would be significantly reduced and thus more lime would be needed to achieve the same level of SO<sub>2</sub> control. More lime will result in higher costs. However, that fact does not mean that the conversion of the current scrubber to a lime-based scrubber would not be cost effective. Even if the costs of the conversion of the current scrubbers to lime-based scrubbers were tripled or quadrupled (i.e., \$1,458/ton to \$1,944/ton) due to the need for additional lime, the cost per ton of SO<sub>2</sub> removed to meet a 0.15 lb/MMBtu SO<sub>2</sub> emission limit would be less than the average costs that are being required to meet SO<sub>2</sub> BART at similar coal-fired EGUs.

Even a tripling or quadrupling of the total annual costs given in Table 4.1-4 of PPL Montana's June 2008 Addendum to the Colstrip BART Report would equate to cost effectiveness values of \$1,458 to \$1,944 per ton of SO<sub>2</sub> removed. This is less than the average cost for EGUs to meet BART controls of \$1,967/ton removed, and it is within range of costs for scrubber upgrades that are being required as BART. For example, Jim Bridger Units 1-4 are all required to upgrade scrubbers to meet an SO<sub>2</sub> emission limit of 0.15 lb/MMBtu, and the cost effectiveness of these controls was projected to be \$620-729/ton of SO<sub>2</sub> removed. Id. Laramie River Units 1 and 3 are required to upgrade scrubbers to meet a 0.15 lb/MMBtu limit and the cost effectiveness of these controls is estimated to be \$1,564-\$1,571/ton of SO<sub>2</sub> removed. Id.

The installation of baghouses upstream of scrubbers at other facilities has not impacted their ability to meet low levels of SO<sub>2</sub>.<sup>54</sup> Several EGUs with existing particle/SO<sub>2</sub> scrubbers

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<sup>53</sup> Although PPL Montana asserted that the scrubbers could achieve 91% SO<sub>2</sub> removal and a 0.15 lb/MMBtu emission limit, this removal efficiency appears to be based on the uncontrolled SO<sub>2</sub> emissions in the coal rather than the uncontrolled SO<sub>2</sub> emission rate at the inlet to the scrubber. An SO<sub>2</sub> emission limit of 0.15 lb/MMBtu reflects only 88% to 89% SO<sub>2</sub> removal across the scrubber based on current coal characteristics at Colstrip.

<sup>54</sup> Unfortunately, the Nevada Division of Environmental Protection proposed an SO<sub>2</sub> BART emission limit for these units of 0.15 lb/MMBtu as a limit that could be continuously met with a reasonable margin of safety, see Revised Nevada Division of Environmental Protection BART

have or soon will install baghouses upstream of the scrubber and will convert the existing PM/SO<sub>2</sub> scrubber into a scrubber focused solely on SO<sub>2</sub> removal. For example, Units 1 – 3 at the Reid Gardner power plant each have venturi scrubbers that are also being used as wet soda ash SO<sub>2</sub> scrubbers. These units added baghouses to meet BART in 2008 and 2009. A review of 2010 SO<sub>2</sub> emissions data from EPA’s Clean Air Markets Database shows that the Reid Gardner Units 1-3 are meeting monthly average SO<sub>2</sub> emission rates of 0.08 lb/MMBtu or less, with 0.06 lb/MMBtu being met on average<sup>55</sup>.

At Cholla Unit 2, which is also equipped with venturi particle scrubbers with lime reagent used for SO<sub>2</sub> control, a baghouse is planned to meet PM BART requirements. The scrubber at this unit will benefit from the reduction in particulate loading which will improve SO<sub>2</sub> removal. Arizona Department of Environmental Quality (AZDEQ) has indicated that it will propose an SO<sub>2</sub> BART limit for Cholla Unit 2 of 0.15 lb/MMBtu.<sup>56</sup>

At Sherburne County Units 1 and 2 which are both equipped with venturi scrubbers with integrated wet ESPs, Minnesota Power proposed to upgrade the scrubbers to meet BART to achieve an SO<sub>2</sub> emission limit of 0.12 lb/MMBtu based on the retrofitting of the existing scrubbers with sparger tubes and lime injection.<sup>57</sup> The cost effectiveness for those scrubber upgrades were projected to be \$237 to 238/ton of SO<sub>2</sub> removed. See National Park Service’s spreadsheet entitled “EGUs with Proposed BART SO<sub>2</sub> Controls,” Attachment 18.

Given that other similar EGUs are installing baghouses and converting existing particle/SO<sub>2</sub> scrubbers to be focused primarily on SO<sub>2</sub> to meet BART, the Colstrip units should be able to do the same. Even if a baghouse or ESP is installed upstream and the Company have to add more lime and/or make additional physical changes to improve SO<sub>2</sub> control, it will likely still be cost effective to upgrade the scrubber to achieve an SO<sub>2</sub> emission limit of 0.15 lb/MMBtu if not lower.

4. EPA should consider the option of requiring the Colstrip Units to replace the wet scrubbers with new wet or dry scrubbers to meet SO<sub>2</sub> BART.

The Company has claimed that it is not required to evaluate the option of installing new SO<sub>2</sub> controls because its scrubbers are achieving at least 50% SO<sub>2</sub> removal. This is incorrect as

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Determination Review of NV Energy’s Reid Gardner Energy Station Units 1, 2, and 3, Revised October 22, 2009, at 8 (Attachment 20), which provides too high of a compliance margin than appears necessary based on current SO<sub>2</sub> data and which does not appear to comply with a proper BART determination.

<sup>55</sup> See Attachment 19, Spreadsheet with monthly emissions data for Reid Gardner Units 1-3 from 2010, downloaded from EPA’s Clean Air Markets Database.

<sup>56</sup> See “Arizona Regional Haze BART Summary” available at <http://www.azdeq.gov/environ/air/haze/index.html>.

<sup>57</sup> See Best Available Retrofit Technology Analysis for Sherburne County Generating Plant Units 1 and 2, October 25, 2006 at 27 (Attachment 21).

EPA's BART guidelines do not preclude evaluation of replacement flue gas desulfurization equipment. If the Company claims it cannot upgrade its existing scrubbers to meet high levels of SO<sub>2</sub> control, then the option of entirely new SO<sub>2</sub> scrubbers at each unit should be evaluated as BART. New scrubbers could provide significant benefits in terms of greatly reduced SO<sub>2</sub> emissions compared to the 0.15 lb/MMBtu emission limit evaluated in the Company's SO<sub>2</sub> BART analysis.

Wet scrubbers can achieve 99% removal efficiency. A prime example is the Chiyoda CT-121 FGD. Vendor information for this technology indicates that this scrubber has achieved 98-99% SO<sub>2</sub> removal even with low sulfur coal.<sup>58</sup> For example, the Chiyoda's bubbling jet reactor has consistently achieved >99% SO<sub>2</sub> removal during long-term operation at the Shinko-Kobe power plant in Japan. This facility consists of two 700-MW coal-fired utility boilers. The wet FGD was designed to achieve 0.014 lb SO<sub>2</sub>/MMBtu (9 ppmv at 3% oxygen) on an instantaneous basis and has consistently exceeded this level of control while treating gases with inlet SO<sub>2</sub> concentrations of 1.78 lb/MMBtu.<sup>59</sup> This technology has been guaranteed by Chiyoda to achieve 99% SO<sub>2</sub> removal on three coal-fired boilers in Japan.<sup>60</sup> It also has been demonstrated in the U.S. at the University of Illinois's Abbott power plant, Georgia Power's Plant Yates<sup>61</sup>, Dayton Power & Light's Killen Unit 2,<sup>62</sup> and Plant Bowen Unit 3.<sup>63</sup> It has also been licensed for installation on several additional units in the US, including the other three units at Plant Bowen in Georgia, the other units at Dayton Power & Light's Killen plant, Dayton Power & Light's Stuart plant, and AEP's Big Sandy Unit 2, Conesville Unit 4, Cardinal Units 1 and 2, and Kyger Creek, among others.<sup>64</sup> Black & Veatch and Southern Company are both U.S. licensees. Further, this technology also has shown to be very effective in removing fine particulates, oxidized and elemental mercury, and acid gases, and the technology uses less energy compared

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<sup>58</sup> See Black & Veatch vendor brochure on CT-121, Attachment 24.

<sup>59</sup> Yasuhiko Shimogama, Hirokazu Yasuda, Naohiro Kaji, Fumiaki Tanaka, and David K. Harris, Commercial Experience of the CT-121 FGD Plant for 700 MW Shinko-Kobe Electric Power Plant, Paper No. 27, presented at MEGA Symposium, Air & Waste Management Association, May 19-22, 2003, Attachment 25.

<sup>60</sup> CT-121 FGD Process – Jet Bubbling Reactor, <http://www.bwe.dk/fgd-ct121.html>.

<sup>61</sup> Emission-control Technologies Continue to Clear the Air, *Power*, May/June 2002.

<sup>62</sup> See Black & Veatch, First Black&Veatch/Chiyoda Wet Flue Gas Desulfurization System in North America Successfully Goes Operational, available at [http://www.bv.com/Downloads/Resources/Brochures/rsrc\\_ENR\\_FirstWetFlueGasDesulfurization.pdf](http://www.bv.com/Downloads/Resources/Brochures/rsrc_ENR_FirstWetFlueGasDesulfurization.pdf).

<sup>63</sup> Blankinship, Steve, Go Take a Bath, *Power Engineering*, October 2008, available at [http://pepei.pennnet.com/display\\_article/342997/6/ARTCL/none/none/1/Go-Take-a-Bath/](http://pepei.pennnet.com/display_article/342997/6/ARTCL/none/none/1/Go-Take-a-Bath/).

<sup>64</sup> Chiyoda Licenses Its Flue Gas Desulfurization Technology in USA Newly for 5 Coal-Fired Generation Units, Press Release, May 2, 2005 ([http://www.chiyoda-corp.com/news/en/2005/post\\_53.html](http://www.chiyoda-corp.com/news/en/2005/post_53.html)); Chiyoda Licenses its Flue Gas Desulfurization Process in USA for Georgia Power Owned 4 FGD Units, January 26, 2005 ([http://www.chiyoda-corp.com/news/en/2005/post\\_17.html](http://www.chiyoda-corp.com/news/en/2005/post_17.html)).

to traditional wet scrubbers. Mitsubishi, a vendor of scrubber systems, reports it has guaranteed SO<sub>2</sub> removal efficiencies up to 99.8 percent, including for coal-fired boilers.<sup>65, 66, 67</sup>

If the Company installed new state-of-the-art wet scrubbers at Colstrip Units 1 and 2, SO<sub>2</sub> emission limits should be based on no less than 99% SO<sub>2</sub> removal. Ninety-nine percent SO<sub>2</sub> removal would equate to an emission limit of less than 0.014 lb/MMBtu. This would equate to SO<sub>2</sub> reductions of approximately 6,128 tons at each unit, compared to the company's projected 3,969 tpy SO<sub>2</sub> reduction with the addition of lime to the existing wet scrubbers to meet a 0.15 lb/MMBtu limit<sup>68</sup>.

A new state-of-the-art dry scrubber can achieve up to 95% SO<sub>2</sub> removal efficiency.<sup>69</sup> Dry scrubbers are commonly used at low sulfur subbituminous coal-fired units for SO<sub>2</sub> control. With 95% control, the Colstrip units could meet SO<sub>2</sub> emission limits of 0.08 lb/MMBtu. This would equate to SO<sub>2</sub> reductions of 5,081 tons per year at each unit. Conversion to dry scrubbing would have a significant co-benefit of limiting the wet waste stream that is disposed of in on-site holding ponds that leak and have caused well-documented groundwater contamination.<sup>70</sup>

Either a new wet scrubber or a new dry scrubber would provide for significant further reductions beyond the SO<sub>2</sub> reductions projected by the Company with upgrades to the scrubbers to achieve a 0.15 lb/MMBtu SO<sub>2</sub> limit. Such new controls have been required as BART for SO<sub>2</sub>. For example, Dave Johnston Unit 4 has an existing venturi scrubber that is designed to achieve 60% SO<sub>2</sub> removal.<sup>71</sup> This unit is being required to install a new dry scrubber and a

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<sup>65</sup> Jonas S. Klingspor, Kiyoshi Okazoe, Tetsu Ushiku, and George Munson, High Efficiency Double Contact Flow Scrubber for the U.S. FGD Market, Paper No. 135 presented at MEGA Symposium, Air & Waste Management Association, May 19-22, 2003, p.8, Table 4, Attachment 26.

<sup>66</sup> Yoshio Nakayama, Tetsu Ushiku, and Takeo Shinoda, Commercial Experience and Actual-Plant-Scale Test Facility of MHI Single Tower FGD, Attachment 27.

<sup>67</sup> Mitsubishi High SO<sub>2</sub> Removal Experience, Attachment 28.

<sup>68</sup> Projected emission reductions were calculated based on the average heat input capacity per boiler of 3,940 MMBtu/hr and an assumed 92% design capacity factor. See June 2008 Addendum to PPL Montana's Colstrip BART Report, Ex. 2, Table 4.1-3. This table includes PPL Montana's projected SO<sub>2</sub> emission reductions under a 0.15 lb/MMBtu emission limit.

<sup>69</sup> See discussion of Acid Gas/SO<sub>2</sub> Control Technologies on the Institute of Clean Air Companies website at <http://www.icac.com/i4a/pages/index.cfm?pageid=3401>.

<sup>70</sup> Wyoming's BART analysis for the Dave Johnston power plant in Wyoming would require PacifiCorp to replace the existing Unit 4 wet venturi scrubber with a full-scale fabric filter for PM control. See Attachment 10 at 49. And although not adopted by Wyoming, PacifiCorp proposed a fabric filter and dry FGD in place of the wet venturi scrubber as BART for SO<sub>2</sub>. Id. A similar conversion to dry handling should also be feasible for Colstrip.

<sup>71</sup> See Weilert, Carl & Emily Meyer, Burns & McDonnell, Utility FGD Design Trends at 11 (Attachment 29).

baghouse to meet BART for SO<sub>2</sub> and PM, and the cost for SO<sub>2</sub> control to meet a 0.15 lb/MMBtu limit was projected to be \$4,743/ton of SO<sub>2</sub> removed. See National Park Service's spreadsheet entitled "EGUs with Proposed BART SO<sub>2</sub> Controls," Attachment 18. This new scrubber at a unit with an existing scrubber has been determined to be cost effective as BART for SO<sub>2</sub>, and thus the Colstrip units should not be exempt from such an analysis to determine if installation of a new scrubber is necessary to meet BART requirements.

In summary, EPA should evaluate the addition of new scrubbers to ensure that Colstrip Units 1 and 2 are equipped with the best continuous system of SO<sub>2</sub> emission reduction. If the costs of control are reasonable when compared to the costs of control that other EGUs are required to incur to meet BART requirements, then such controls should be required as BART. There is no question that such controls will improve visibility in Montana's Class I areas, given that the Company already showed that just meeting an SO<sub>2</sub> emission limit of 0.15 lb/MMBtu based on lime injection to the scrubbers would provide for noticeable improvement in visibility – as is discussed below.

5. Upgraded SO<sub>2</sub> controls will provide noticeable benefits to regional haze in Class I areas.

Scrubber upgrades or replacement would significantly improve visibility. The Company modeled the visibility improvements expected from upgrades to the scrubber to comply with what they claimed to be 91% control, an emission limit of 0.15 lb/MMBtu (which more likely reflects 89% SO<sub>2</sub> removal across the scrubber as discussed above). The Company's modeling found that there would be an improvement in the 98<sup>th</sup> percentile visibility impacts of 0.544 deciviews. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 4-3. A 0.5 deciview impact is considered a "noticeable change" and is the threshold EPA has identified for determining whether an existing source contributes to visibility impairment in a Class I area. 40 C.F.R. Part 51, Appendix Y, Section III.A.1. Thus, the improvement to visibility if the scrubbers at the Colstrip Units 1 and 2 were upgraded to meet a 0.15 lb/MMBtu SO<sub>2</sub> emission limit would provide a noticeable benefit to visibility. Consequently, the Company has shown it can cost effectively upgrade the scrubbers to achieve an SO<sub>2</sub> limit of 0.15 lb/MMBtu and that it will noticeably improve visibility. Based on the information we provided above, we think it is likely the units can reduce SO<sub>2</sub> even further while still being cost effective, and such additional SO<sub>2</sub> emission reductions will only further improve visibility in the Class I areas in the region.

6. Related environmental benefits of improved SO<sub>2</sub> removal efficiency.

With improved SO<sub>2</sub> removal efficiency at Colstrip Units 1 and 2, there will be other pollutants that will be reduced as a co-benefit of the SO<sub>2</sub> controls. Specifically, acid gas hazardous air pollutants such as hydrogen chloride and hydrogen fluoride will be reduced to a greater extent with a more efficient scrubber at Colstrip Units 1 and 2. In fact, the Colstrip Units 1 and 2 might require scrubber upgrades to meet EPA's forthcoming acid gas MACT requirements. EPA has proposed acid gas MACT limits for HCl of 0.002 lb/MMBtu or, alternatively, EGUs can select to comply with a surrogate limit on SO<sub>2</sub> of 0.20 lb/MMBtu. 76 Fed. Reg. 25127 (May 3, 2011). Colstrip Units 1 and 2 emit SO<sub>2</sub> at twice the rate of the EPA's proposed surrogate SO<sub>2</sub> MACT limit, so they will likely be required to upgrade SO<sub>2</sub> removal

efficiency to meet acid gas MACT requirements. The Colstrip units will have to comply with the acid gas MACT requirements by the end of 2014, which is a similar requirement for BART compliance. Thus, EPA should take into account the forthcoming MACT rules in determining SO<sub>2</sub> BART for Colstrip Units 1 and 2. Improving SO<sub>2</sub> control will greatly improve control of acid gas toxic emissions.

In addition, improved efficiency of the scrubbers at Colstrip Units 1 and 2 will also result in reductions on condensable PM, which will not only benefit visibility but will also help the Colstrip units to comply with EPA's proposed 0.03 lb/MMBtu MACT standard on total PM emissions that EPA has proposed as a surrogate for non-mercury metal hazardous air pollutants. Further, given that condensable PM emissions are typically in the range of 2.5 microns or smaller, improved efficiency of the scrubbers will result in less PM<sub>2.5</sub> being emitted from Colstrip Units 1 and 2. These additional benefits need to be taken into account when determining BART for SO<sub>2</sub>.

Further, replacing the existing wet scrubber with a state-of-the-art dry scrubber could significantly limit the amount of wet waste stored in the Company's leaking holding ponds. Indeed, the Company may be required to switch to dry handling procedures in any event to address ongoing violations of its state Major Facility Siting Act certificate of compliance. Investment in dry scrubbing technology would therefore serve the additional purpose of reducing harmful groundwater contamination due to the Company's leaking holding ponds.

In sum, the Company has shown that it is extremely cost effective to upgrade the existing scrubbers to add lime injection to meet an SO<sub>2</sub> emission limit of 0.15 lb/MMBtu, and the company has shown that meeting such a limit will provide for noticeable improvements to visibility. Based on this analysis, the Company must at least upgrade the existing scrubbers to add lime injection and meet a 0.15 lb/MMBtu SO<sub>2</sub> BART limit. Even with the installation of a baghouse upstream of the existing scrubber to meet BART for PM (as well as to meet mercury requirements and MACT for toxic metals), upgrading the scrubber to achieve an SO<sub>2</sub> emission rate of at least 0.15 lb/MMBtu would be cost effective when compared to the costs that other EGUs are subject to under BART requirements. Moreover, given that a 0.15 lb/MMBtu SO<sub>2</sub> emission limit does not even reflect 90% SO<sub>2</sub> control across the boiler, EPA must evaluate additional scrubber upgrades and new replacement scrubbers that could enable greater reductions in SO<sub>2</sub> emissions and greater benefits to regional haze.

#### **E. Cumulative Impact and Benefit Must be Considered as Part of Fifth Step in BART Analysis**

The cumulative impact of a Colstrip's emissions on visibility as well as the cumulative benefit of emission reductions must be considered as part of the fifth step in the BART analysis. In this regard we support the National Park Service's reasoning as articulated in the agency's comments on Salt River Project's proposed BART determination for Navajo Generating Station, July 24, 2009:

...[I]t is appropriate to consider both the degree of visibility improvement in a given Class I area as well as the cumulative effects of improving

visibility across all of the Class I areas affected. It simply does not make sense to use the same metric to evaluate the effects of reducing emissions from a BART source that impacts only the one Class I area as for a BART source that impacts multiple Class I areas. And, it does not make sense to evaluate impacts at one Class I area, while ignoring others that are similarly significantly impaired. If we look at only the most-impacted Class I area, we ignore that the other Class I areas are all suffering from impairment to visibility “caused” by the BART source. It follows that, if emissions from the BART source are reduced, the benefits will be spread well beyond only the most impacted Class I area, and this must be accounted for.

Emissions from Colstrip cause or contribute to visibility impairment at five pristine Class I area parks and wilderness areas. Considering impacts to UL Bend alone, as Puget Sound does in its BART analysis, discounts the facility’s contributions to visibility impairment in four other Class I areas as well as the potential benefit, and therefore incentive, of reducing haze-causing emissions from the source. Multiple states and EPA regions as well as the federal land management agencies have assessed the cumulative impact and benefits of BART sources within their jurisdiction. We encourage EPA Region 8 to ensure that BART analyses are inclusive of cumulative impacts and benefits that reflect the degree of visibility improvement which may reasonably be anticipated from the use of BART.

### **III. REASONABLE PROGRESS REQUIREMENTS FOR COLSTRIP UNITS 3 AND 4**

The FIP should establish emissions controls for Colstrip Units 3 and 4 as part of its long-term strategy for achieving reasonable progress toward meeting natural visibility conditions at mandatory Class I areas by 2064. 40 C.F.R. § 51.308(d)(1)(i)(B). The FIP’s reasonable progress goals “must provide for improved visibility on the most impaired days and ensure no degradation in visibility for the least impaired days.” *Id.* In developing its long-term strategy for meeting reasonable progress goals, EPA must consider all anthropogenic sources of visibility impairment and evaluate different emission reduction strategies beyond those prescribed by the BART provisions. 40 C.F.R. §51.308(d). EPA should consider “major and minor stationary sources, mobile sources and area sources.” *Id.* Given the substantial contribution of Colstrip Units 3 and 4 to visibility impairment in the region’s Class I areas, EPA’s long-term strategy for meeting reasonable progress goals must include emissions limitations for these units.

#### **A. Colstrip Units 3 and 4 Should Be Required to Reduce NO<sub>x</sub> to Meet Reasonable Progress Requirements.**

To ensure it meets reasonable progress requirements, EPA must consider imposing SCR on Colstrip Units 3 and 4. At a minimum, regardless of BART applicability and determinations, EPA is required to demonstrate that “it has included in its implementation plan all measures necessary to obtain its share of the emission reductions needed to meet the progress goals for the area,” even when sources from outside the state contribute to visibility impairment in the State’s Class I areas. 40 C.F.R. § 51.308(d)(3)(ii) (emphasis added). Further, EPA has a responsibility

to reduce emissions from Montana sources that are reasonably anticipated to impact visibility in other states' Class I areas. To this end, EPA should impose SCR on all four Colstrip units.

The Colstrip plant is the largest industrial source of NO<sub>x</sub> in the State of Montana. Units 3 and 4, being larger units than Units 1 and 2, emit roughly two-thirds of the NO<sub>x</sub> from the Colstrip power plant. Although these units recently upgraded combustion controls to reduce NO<sub>x</sub> emissions, the NO<sub>x</sub> emission rates at these units are still high. Specifically, Colstrip Units 3 and 4 are achieving annual average NO<sub>x</sub> emission rates of 0.17 lb/MMBtu, according to the Company. See January 31, 2011 submittal from PPL Montana to EPA regarding Colstrip Units 3 and 4, Ex. 2 at 6.

The Company's January 2011 submittal to EPA appears to state that Colstrip Units 3 and 4 are already meeting BART for NO<sub>x</sub>, and thus the PPL Montana did not evaluate any additional NO<sub>x</sub> controls. Specifically, the submission discusses the 2007 Consent Decree that includes requirements to satisfy Condition 7 of its 1979 prevention of significant deterioration (PSD) permit. Id., Ex. 2 at 4. Condition 7 of their PSD permit required the company to conduct a "BART analysis" for NO<sub>x</sub> to address visibility impairment that the Colstrip Units 3 and 4 were projected to cause on the Northern Cheyenne Indian Reservation Class I area. Id.

Contrary to the Company's interpretation, the "BART" requirement in Condition 7 is not equivalent to BART under the Regional Haze Rule. Condition 7 was included in the Colstrip Units 3 and 4 PSD permit to address what is known as "reasonably attributable" visibility impairment, where visibility impairment in a Class I area is reasonably attributable to a source. Further, Condition 7 was included to address visibility impairment for a non-mandatory Class I area—the Northern Cheyenne Indian Reservation. See 40 C.F.R. §51.301. In contrast, regional haze applies to Mandatory Class I Federal Areas and it applies to visibility impairment that is caused by numerous sources located over a wide geographic area. Id. Further, EPA's BART guidelines require a case-by-case, five-factor analysis to determine what represents BART for a particular facility. To the best of our knowledge, the Company has not submitted a BART analysis under the requirements of EPA's BART guidelines in 40 C.F.R. Part 51, Appendix Y. The 2007 consent decree addressed a permit violation, not a regional haze requirement. Thus, the Company's claim that the 2007 consent decree exempts Units 3 and 4 from a complete BART analysis to determine what pollution controls can be cost effectively applied to meet reasonable progress goals of the regional haze program is not accurate. Indeed, the "reasonable progress" requirement envisions emissions controls above and beyond existing permit requirements, and even beyond BART. See 40 C.F.R. §51.308(d).

It would be difficult to support the NO<sub>x</sub> requirements of the Consent Decree as meeting BART. Specifically, the Consent Decree specifies NO<sub>x</sub> limits of 0.18 lb/MMBtu when loads are above 400 MW and 0.30 lb/MMBtu when loads are less than or equal to 400 MW, applicable on a 30-day rolling average. The Consent Decree also sets 24-hour average limits of 0.25 lb/MMBtu at loads above 400 MW and 0.30 lb/MMBtu at loads less than or equal to 400 MW. See January 31, 2011 submittal from PPL Montana to EPA regarding Colstrip Units 3 and 4, Ex. 2 at 1-2. The Company states that Units 3 and 4 are emitting NO<sub>x</sub> at a rate of 0.17 lb/MMBtu on an annual average basis. Id. at 6. While one cannot readily compare annual average NO<sub>x</sub> emission rates to 30-day or 24-hour average emission rates, the annual average NO<sub>x</sub> rates

indicate that the units are likely operating well below the emission limits of the Consent Decree, especially the emission limits that apply at lower loads below 400 MW. Indeed, it is not clear why such higher limits at lower loads are even necessary. EPA's presumptive BART limits in 40 C.F.R. Part 51, Appendix Y, do not include provisions for increased NOx emission rates at lower loads, and yet the majority of EPA's presumptive NOx limits are based on the use of combustion controls like low NOx burners and overfire air.<sup>72</sup> In fact, if Colstrip Units 3 and 4 need higher NOx limits during lower loads, this indicates that the low NOx concentric firing burners and separated overfire air currently installed at Colstrip Units 3 and 4 do not reflect the best system of continuous emission reduction required to meet BART.

Clearly, these units also are not achieving emission rates reflective of the best system of NOx reductions for coal-fired utility boilers. The units' NOx emissions do not even meet the current New Source Performance Standards (NSPS) of 0.11 lb/MMBtu (30-day average) for a new unit to 0.15 lb/MMBtu (30-day average) for a modified unit. 40 C.F.R. §60.44Da(e)(2). The units are also not meeting the presumptive NOx BART limit for tangentially-fired units like Colstrip Units 3 and 4 of 0.15 lb/MMBtu. Thus, these Colstrip units can achieve lower NOx emission rates and, clearly, the emission limits of the Consent Decree are not reflective of BART or emission limits necessary to meet reasonable progress goals under the regional haze program.

It is also questionable that the low NOx concentric firing burners with SOFA currently installed at Colstrip Units 3 and 4 reflect state-of-the-art combustion controls, given that Units 3 and 4 are only achieving 0.17 lb/MMBtu on an annual average. As previously discussed in this letter regarding NOx BART for Colstrip Units 1 and 2, ultra low NOx burners are available that can achieve NOx emission rates lower than 0.17 lb/MMBtu, as low as 0.13 lb/MMBtu.<sup>73</sup>

SCR is the best choice to reduce NOx at Colstrip Units 3 and 4, due to the very low NOx emission rates that can be achieved and the significant benefits to visibility that could be obtained with SCR. As we have discussed in this letter regarding Colstrip Units 1 and 2, Colstrip Units 3 and 4 should be able to easily achieve NOx emission rates of 0.04 lb/MMBtu or lower with SCR. Such emission rates have been required to meet best available control technology and other requirements and have been achieved in practice at numerous units.<sup>74</sup> Given how the Company's cost evaluation of SCR for Colstrip Units 1 and 2 showed that SCR would be cost effective when compared to the costs that other power plant owners have to meet under regional haze requirements, one would expect the cost effectiveness calculations for installation of SCR at Colstrip Units 3 and 4 to be even more cost effective due to economies of scale and the fact that Units 3 and 4 are larger units. If SCR was installed at Colstrip Units 3 and 4, the units could achieve additional NOx reductions of roughly 4,300 tons per year each from

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<sup>72</sup> See 40 C.F.R. Part 51, Appendix Y, Table 1; see also Technical Support Document for BART NOx Limits for Electric Generating Units and Technical Support Document for BART NOx Limits for Electric Generating Units Excel Spreadsheet, Memorandum to Docket OAR 2002-0076, April 15, 2005.

<sup>73</sup> See Attachment 1.

<sup>74</sup> See Attachments 3, 4, and 5.

current NOx emission levels.<sup>75</sup> The Company's SCR analysis for Units 1 and 2 assumed similar levels of NOx reductions from Colstrip Units 1 and 2 and their modeling showed a 0.956 deciview improvement in visibility impairment from installation of SCR at Units 1 and 2. See June 2008 Addendum to PPL Montana's Colstrip BART Report at 5-6 and Appendix 2 (Table 5.5-3). Similar improvements in visibility should occur with the installation of SCR at Colstrip Units 3 and 4. Thus, installation of SCR at Colstrip Units 3 and 4 should significantly improve visibility.

In summary, EPA must evaluate additional controls on NOx emissions from Colstrip Units 3 and 4 to address Montana's largest source of NOx emissions and to provide reasonable progress towards the national visibility goal in the Montana, Wyoming, and North Dakota Class I areas impacted by the Colstrip power plant. Based on the information provided for NOx BART for Colstrip Units 1 and 2, SCR should be required at Colstrip Units 3 and 4 as the most cost effective controls that provide for the greatest benefit to regional haze.

**B. EPA Must Adopt Reasonable Progress Requirements Pertaining to the SO2 and PM Emitted by Colstrip Units 3 and 4.**

Additional SO2 and PM controls are also justified for Colstrip Units 3 and 4 to meet reasonable progress requirements. The Company has indicated that it cannot cost effectively upgrade the PM controls at Colstrip Units 3 and 4 because the SO2 scrubber efficiency depends on the utilization of alkaline fly ash. Thus, the company indicated that if a baghouse or an ESP was installed upstream of the scrubber, they would likely need to also install new limestone forced oxidation scrubbers to achieve the same levels of SO2 emissions. According to the Company, Colstrip Units 3 and 4 are achieving 95% SO2 removal and annual average emission rates of 0.08 lb/MMBtu. See January 31, 2011 submittal from PPL Montana to EPA regarding Colstrip Units 3 and 4, Ex. 2 at 8. Unlike the scrubbers at Colstrip Units 1 and 2, the company adds lime to the scrubbers at Units 3 and 4 and each has a spare absorber. The company has estimated that the combined costs of installing a baghouse or an ESP and a new scrubber at each unit would be one billion dollars in total for both units. Id. at 17-18.

There are several examples of EGUs with venturi scrubbers that have or soon will install baghouses or ESPs upstream of scrubbers, and no issues of reduced SO2 removal have been raised. In the discussion of PM BART for Colstrip Units 1 and 2 in this letter, we have provided examples of other power plant units that have installed, or soon will install, baghouses upstream of particle/SO2 scrubbers without negatively impacting SO2 emissions. Those EGUs include Reid Gardner Units 1-3, Cholla Unit 2, and Sherburne County Units 1 and 2.<sup>76</sup> EPA Region 9 has also proposed that the Four Corners Power Plant Units 1-3 install PM controls upstream of existing particle/SO2 scrubbers to meet BART for PM, and EPA has not identified any concerns

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<sup>75</sup> This was calculated based on the average annual heat input for Unit 3 from 2008-2009 for Unit 3 and 2007-2008 for Unit 4 (due to the lengthy period that Unit 4 was not operated in 2009), assuming current NOx emission rates of 0.17 lb/MMBtu and a controlled NOx emission rate with SCR of 0.04 lb/MMBtu.

<sup>76</sup> See, e.g., Attachments 20 and 21.

with the reduced levels of SO<sub>2</sub> removal due to the removal of ash upstream of the scrubbers.<sup>77</sup> Thus, we question the Company's assumption that it could not operate or, if necessary, upgrade its existing scrubbers to achieve the same levels of SO<sub>2</sub> removal if a baghouse or ESP were added upstream of the scrubbers. For example, the Company could add more lime and/or make other physical changes to the scrubber to improve the effectiveness of the scrubber if a baghouse was added upstream of the current scrubber. See discussion on PM BART for Colstrip Units 1 and 2 and Attachments 22 and 23 for further details on the upgrades that could be done to the scrubbers if the scrubber was designed and operated solely for SO<sub>2</sub> removal.

EPA Region 9 found that the particle scrubbers at Four Corners Units 1-3 were causing a secondary plume that was adversely impacting visibility. Region 8 should conduct a similar analysis for the Colstrip power plant units. As Region 9 stated, venturi particle scrubbers are hardly used anymore for particulate control at coal-fired EGUs due to their substandard removal of particulates, and especially fine particulates, in comparison to a baghouse or ESP. See 75 Fed. Reg. 64231 (Oct. 19, 2010). If the scrubbers at Colstrip are causing a secondary plume, then installation of a baghouse or an ESP upstream of the scrubber will significantly improve visibility.

In addition, Colstrip Units 3 and 4 will likely need to upgrade PM controls to meet EPA's forthcoming MACT rule. Specifically, EPA has proposed a PM limit of 0.03 lb/MMBtu as a surrogate for non-mercury metal HAPs. EPA's proposed limit is a limit on total particulate matter (filterable plus condensable PM). The Colstrip Units 3 and 4 emitted filterable PM at a rate of 0.026 lb/MMBtu on average over the past five years. See January 31, 2011 submittal from PPL Montana to EPA regarding Colstrip Units 3 and 4, Ex. 2 at 15. With condensable PM added in, these units undoubtedly emit total PM at rates exceeding EPA's proposed PM MACT standard of 0.03 lb/MMBtu. Thus, the Company will likely need to upgrade PM controls and/or SO<sub>2</sub> controls to meet EPA's proposed MACT limit on total PM of 0.03 lb/MMBtu. Further, improvements in PM controls may be necessary to meet EPA's proposed mercury MACT limits, as discussed in this letter regarding Colstrip Units 1 and 2. EPA should consider these future regulations in determining regional haze plan requirements for Colstrip Units 3 and 4. If the units are going to have to install PM controls, whether upstream or downstream of the scrubbers, to meet MACT, then EPA should impose appropriate emission limits in the regional haze plan reflective of these forthcoming rules and the benefits that these forthcoming rules will have for visibility in the Class I areas in the region.

Further, the Colstrip Units 3 and 4 are emitting SO<sub>2</sub> at much lower rates than currently allowed in the applicable requirements. Specifically, although Units 3 and 4 are currently emitting SO<sub>2</sub> at a rate of 0.08 lb/MMBtu, the units are subject to much less restrictive SO<sub>2</sub> emission limits of 0.18 lb/MMBtu on a calendar day average. See January 31, 2011 submittal from PPL Montana to EPA regarding Colstrip Units 3 and 4, Ex. 2 at 8; see also May 17, 2011 draft Title V permit, Section III.C. at 12. Thus, EPA should impose SO<sub>2</sub> limits on Colstrip Units 3 and 4 in the regional haze SIP that are reflective of the 0.08 lb/MMBtu SO<sub>2</sub> emission

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<sup>77</sup> See 75 Fed. Reg. 64320-2 (Oct. 19, 2010); see also Attachment 11.

rate currently being achieved at these units to ensure that no future degradation in visibility due to these units' SO2 emissions is allowed.

For all of the above reasons, EPA should, at the minimum, impose PM limits reflective of compliance with its proposed MACT standards and impose SO2 limits reflective of current levels of SO2 emission rates in the Montana regional haze plan. EPA must impose limits that ensure reasonable progress towards the national visibility goal and also ensure the prevention of any future visibility impairment due to SO2 and PM emissions from Colstrip Units 1 and 2.

We thank you for your consideration of these comments and would be pleased to answer any questions you have. We look forward to our meeting on August 25, 2011.

Sincerely,



Jenny Harbine  
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Sanjay Narayan and Doug Howell, Sierra Club  
Stephanie Kodish, National Parks Conservation Association  
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## ATTACHMENTS

Attachment Number	Description
1	Bryk, S.A. et al., First Commercial Application of DRB-4Z™ Ultra Low NOx Coal-Fired Burner, presented to POWER-GEN International 2000, November 14-16, 2000, Orlando, FL.
2	National Park Service’s Spreadsheet “EGUs with proposed BART NOx Controls Mar 2011.”
3	Institute of Clean Air Companies, White Paper Selective Non-Catalytic Reduction (SNCR) for Controlling NOx Emissions, May 2000.
4	Erickson, Clayton A. et al., Selective Catalytic Reduction System Performance and Reliability Review, The 2006 MEGA Symposium, Paper # 121.
5	Desert Rock PSD permit.
6	National Park Service spreadsheet on BACT limits for New PC Power Plants.
7	Florida Source Tests compilation.
8	Matt Haber, <i>Best Available Control Technologies for the Baldwin Generating Station, Baldwin, Illinois, Expert Report</i> , Prepared for the United States in connection with U.S. v. Illinois Power Company and Dynegy Midwest Generation, Inc., April 2002.
9	May 28, 2009 WY DEQ BART Application Analysis for Pacificorp Naughton Power Plant.
10	May 28, 2009 WY DEQ BART Application Analysis for Pacificorp Dave Johnston Power Plant.
11	EPA’s Technical Support Document, Proposed Rule: Source Specific Federal Implementation Plan for Implementing Best Available Retrofit Technology at Four Corners Power Plant: Navajo Nation.
12	McIlvaine Hot Topic Hour, Filter Media Selection for Coal-Fired Boilers, September 13, 2007, Presentation by Todd Brown, Daikin America, Inc.
13	USEPA, <i>ETV Joint Verification Statement, Baghouse Filtration Products</i> , W.L. Gore & Associates, L3650.
14	US EPA, Performance and Cost of Mercury and Multi-Pollutant Emission Control Technology Applications on Electric Utility Boilers, EPA-600/R03-110 (October 2003).
15	US EPA Region 9, Ambient Air Impact Report for Desert Rock Energy Project.
16	EPRI’s “Estimating Total Sulfuric Acid Emissions from Stationary Power Plants,” Version 2010a.
17	EPA, Regulatory Impact Analysis of the Proposed Toxics

	Rule: Final Report, March 2011.
18	National Park Service's spreadsheet entitled "EGUs with Proposed BART SO2 Controls.
19	Spreadsheet with monthly emissions data for Reid Gardner Units 1-3 from 2010, downloaded from EPA's Clean Air Markets Database.
20	Revised Nevada Division of Environmental Protection BART Determination Review of NV Energy's Reid Gardner Energy Station Units 1, 2, and 3, Revised October 22, 2009.
21	Best Available Retrofit Technology Analysis for Sherburne County Generating Plant Units 1 and 2, October 25, 2006.
22	Roden, Bob et al., New Magnesium-Enhanced Lime FGD Process, Carmeuse-North America Technology Center, Pittsburgh, PA.
23	Nolan, Paul S., Babcock & Wilcox Co., Flue Gas Desulfurization Technologies for Coal-Fired Power Plants, presented at Coal-Tech 2000 International Conference, November 13-14, 2000, Jakarta, Indonesia.
24	Black & Veatch vendor brochure on CT-121.
25	Yasuhiko Shimogama, Hirokazu Yasuda, Naohiro Kaji, Fumiaki Tanaka, and David K. Harris, Commercial Experience of the CT-121 FGD Plant for 700 MW Shinko-Kobe Electric Power Plant, Paper No. 27, presented at MEGA Symposium, Air & Waste Management Association, May 19-22, 2003.
26	Jonas S. Klingspor, Kiyoshi Okazoe, Tetsu Ushiku, and George Munson, High Efficiency Double Contact Flow Scrubber for the U.S. FGD Market, Paper No. 135 presented at MEGA Symposium, Air & Waste Management Association.
27	Yoshio Nakayama, Tetsu Ushiku, and Takeo Shinoda, Commercial Experience and Actual-Plant-Scale Test Facility of MHI Single Tower FGD.
28	Mitsubishi High SO2 Removal Experience.
29	Weilert, Carl & Emily Meyer, Burns & McDonnell, Utility FGD Design Trends.
30	Carstens, Andrew J. et al., Performance Upgrades for Low-Sulfur Wet Scrubbers, Sargent & Lundy and CPS Energy, Paper # 134, EPRI-DOE-EPA-AWMA Combined Power Plant Air Pollutant Control Mega Symposium, 2008.