Summary of Alternate Compliance Technology Studies

The Company completed eight noteworthy technical studies to evaluate NOx, PM and SO_2 emission control alternative technologies for Naughton Unit 3, the first of which also apply to the Hunter Unit 1 projects included in this docket for review. In October 2002, Sargent and Lundy ("SL") completed a fleet-wide *Multi-Pollutant Control Report* as an attorney-client privileged work product; in January 2005, SL completed a NOx emissions reduction technologies study; in March 2006, SL completed a *Conceptual Design of Replacement Baghouse PacifiCorp Naughton* 3 study; in February 2007, CH2M Hill completed the *BART Analysis for the Naughton Unit 3*; in December 2009, SL completed the *SCR and Baghouse Study Report*; in October 2012, Alstom completed the *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Firing Fuel Heat Input*; in November 2012, SL completed the *Naughton Station Conversion of Unit 3 to 100% Natural Gas Firing* study; and in March 2013, Alstom completed the *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Fuel Input Including Evaluation of Flue Gas Recirculation and Low Load Operation.*

1. The *Multi-Pollutant Control Report* provided an early investigation of the cost and necessity of NOx, particulate matter ("PM") and sulfur dioxide ("SO_2") emission controls on the units.
2. The 2005 NOx emission reduction technologies study compared sixteen emission control technologies, status of the technology development, predicted performance, approximate initial capital costs, and approximate incremental fixed and variable operational and maintenance ("O&M") costs.

3. The *Conceptual Design of Replacement Baghouse PacifiCorp Naughton 3* study established initial capital costs for PM emissions control alternatives.
4. The *BART Analysis for the Naughton Unit 3* was conducted for criteria pollutants NOx, PM_{10} and SO_2. The Company conducted the BART analysis and determination to analyze the effects on visibility in nearby Class I areas (Bridger, Fitzpatrick and Mt. Zirkel Wilderness Areas). A BART analysis is a comprehensive evaluation of potential NOx, PM and SO_2 retrofit technologies, and a BART determination is an emissions limit established by the application of potential retrofit technologies for each unit. The specific steps in a BART analysis are established in 40 CFR 51 Appendix Y, Section IV. The analysis must include: (1) the identification of available and technically feasible retrofit alternatives; (2) consideration of any pollution control equipment in use at the source (which affects the availability of alternatives and their effects); (3) the costs of compliance with control alternatives; (4) the remaining useful life of the facility; (5) the energy and non-air quality environmental impacts of compliance; and (6) the degree of visibility improvement that reasonably may be anticipated from installation of the BART alternative.
5. The *SCR and Baghouse Study Report* evaluated and established design criteria and specified critical equipment features to mitigate design risks for a SCR and baghouse technology alternative.
6. The *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Firing Fuel Heat Input* assessed the boiler thermal performance impacts; firing system

performance and emissions impacts; controls impacts; and potential boiler pressure part and firing system component modifications that may be required to add natural gas firing capability to the unit based on operation with 100% fuel heat input at full load.

7. The *Naughton Station Conversion of Unit 3 to 100% Natural Gas Firing* study investigated the scope of work and estimated costs for converting the unit from a base loaded coal unit to a natural gas fueled peaking unit while leaving coal firing capability intact to the greatest extent practicable.

8. The *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Fuel Input Including Evaluation of Flue Gas Recirculation and Low Load Operation* assessed thermal performance of the unit at low load and provided an evaluation of NOx emissions control using a FGR alternative at both high and low loads.

Key Study Points

Salient points from these eight studies, and related information from other sources, are presented with following statements:

The *Multi-Pollutant Control Report* indicated that combination "in-combustion" (Low NOx Burners with Over Fire Air) and "post combustion" (Selective Catalytic Reduction) would need to be installed on Hunter Unit 1 to achieve a presumptive NOx emission rate of less and 0.10 pounds per million British thermal units (lb/mmBtu)

The *Multi-Pollutant Control Report* indicated that a combination of "in-combustion" and "post-combustion" controls (namely a SCR) would need to be installed on Naughton Unit 3 to achieve a presumptive NOx emissions limit of less than 0.10 pounds per million British thermal units ("lb/mmBtu").

The *Multi-Pollutant Control Report* indicated that the Hunter Unit 1 ESP could achieve a particulate emission level of 0.030 lb/mmBtu with reasonable modifications and upgrades, and it further indicated that that maintenance costs would need to increase over time to facilitate the rebuilds necessary to keep the current equipment operational at historic levels. In order to achieve an emission level below 0.020 lb/mmBtu, the *Multi-Pollutant Control Report* indicated a polishing baghouses retrofit would need to be completed.

The *Multi-Pollutant Control Report* indicated that Naughton Unit 3 would require extensive modifications to the existing ESP or a "polishing baghouse retrofit" must be completed to meet a presumptive PM emissions limit of less than 0.030 lb/mmBtu. The Naughton Unit 3 ESP is the smallest in the Company's coal fleet, is about 40 years old, and is in poor condition. It does have a flue gas conditioning system to improve its performance. Historical operating data establishes that the existing ESP's best PM emissions rate is only approximately 0.04 lb/mmBtu.

The *Multi-Pollutant Control Report* indicated that the Hunter Units 1 FGD system could achieve a removal efficiency of 90% with the following system upgrades: (1) close the scrubber bypass damper (2) upgrade the existing mist eliminators (3) add vertical flow mist eliminators (4) improve inlet gas distribution (5) upgrade existing reheat system (6) upgrade spray header and nozzle system (7) replace existing spray pumps (8) convert to a forced oxidation system (9) restore and upgrade dewatering equipment.

The *Multi-Pollutant Control Report*, and other sources, indicated that a FGD upgrade SO_2 removal efficiency of 90% would be achieved on the existing Naughton Unit 3 FGD with only minor changes including: (1) improvements to the inlet gas distribution; (2) the liquid to gas contact point would need to be reviewed; (3) reagent and waste delivery systems needed to be upgraded; (4) a reagent adjustment; and (5) consideration of a conversion to an open spray type absorber.

At units with high baseline NOx emissions (high is defined here as being greater than 0.40 lb/mmBtu), it is common utility industry practice to initially obtain a NOx emissions reduction through the installation in-combustion modifications, similar to the LNBs installed on the units, and then control the remainder of any required NOx emissions reduction with post-combustion control systems, typically either SCR or a selective non-catalytic reduction system ("SNCR").

NOx control technologies are grouped as either *in-combustion* control, *post-combustion* control or *emerging* types:

- In-Combustion Controls include: (1) LNBs with overfire air ("OFA"); (2) more precise combustion control of fuel and air; (3) combustion optimization using a Neural Network system; and (4) Nalco Mobotec rotating opposed fire air ("ROFA" or "rotating opposed fire air") which is a next generation OFA system.

- Post-Combustion Controls include: (1) SNCR, typically limited to only 10 to 40 percent NOx emissions reduction and have higher ammonia slip rates; and (2) SCR with 80 to 90 percent NOx emissions reduction and a low ammonia slip rate.
- Other emerging NOx reduction technologies (and that might become commercially available, or more commercially feasible, within the next decade) with the capability to achieve required NOx removal percentages include: (1) Regenerative Activated Coke Technology; (2) Powerspan Electro-Catalytic Oxidation; (3) BOC LoTOx System; (4) Airborne Process; (5) Consolv Technologies Absorption Process; (6) Lean Gas Reburning; (7) Rich Reagent Injection; (8) SNCR plus SCR hybrid systems; (9) Aptech CST SNCR type systems; and (10) other reagent injection developments.

Of the technology alternatives mentioned herein, only LNB with OFA, ROFA, SNCR with LNB, and SCR with LNB were considered BART analysis feasible alternatives for NOx reduction across the fleet.

In a SCR, ammonia (“NH_3”) reacts with NOx contained in the flue gas exiting the boiler as either nitrogen oxide (“NO”) or nitrogen dioxide (“NO_2”) in the presence of catalyst to form molecular nitrogen (“N_2”) and water (“H_2O”). Catalyst enhances the reaction between ammonia and NOx. The injected air-diluted ammonia is adsorbed on the catalyst surfaces in the SCR reactors and reacts with oxygen and NOx present in the flue gas according to the following chemical reaction equations:

$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$$

$$4NH_3 + 2NO_2 + O_2 \rightarrow 3N_2 + 6H_2O$$

SNCR technology is similar to SCR because it involves injection of an amine reducing agent like urea solution. The reduction chemistry, however, takes place in the boiler without the aid of any catalyst. SNCR relies on appropriate injection temperatures, proper mixing of the reagent and flue gas, reagent injection kinematics, and prolonged boiler detention time in place of the catalyst. SNCR operate at higher temperatures than SCR. The effective temperature range for SNCR is 1,600 to 2,100 degrees F. SNCR is sensitive to temperature changes.

Table NT3-5-1 summarizes a comparison of NOx emissions control technologies results adapted from the *BART Analysis for the Naughton Unit 3* on a 2007 cost year basis: Other environmental project costs not included in the BART estimates include: boiler and air preheater casing structural reinforcements, flue gas path structural reinforcement, a high and low temperature EEGT control system, demolition, auxiliary power system upgrades, Owner’s project costs and a contingency allowance.

Table NT3-5-1: Oxides of Nitrogen Emissions Control Technologies Comparison (Adapted From CH2M Hill BART Analysis)

Technology	Projected Emission Rate (lb/mmBtu)	Projected Emission % Reduction (%) (b)	Capital Cost ($ x million)	O&M Cost Fixed + Variable ($ x million)	Annual Power Usage (1,000 MWh/yr)	First Year Avg. Cost For NOx Removal ($/ton)
Baseline	0.50 (a)	0%	0.0	0.0	0.0	0
LNBs with OFA	0.35	22.2%	0.0 (c)	0.1	0.0	0
ROFA	0.28	37.8%	14.7	1.9	35.3	1,326
Selective Non-Catalytic Reduction and LNBs with OFA	0.28	37.8%	15.8	0.9	2.6	984
Selective Catalytic Reduction and LNBs with OFA	0.07	84.4%	92.0	2.6	15.7	2,049

(a) Emissions from PI data in table below; prior to LNB and OFA installations on Unit 3, the uncontrolled emissions rate was approximately 0.50 lb/mmBtu
(b) Technology reduction rates from the CH2M Hill BART analysis shown
(c) Currently installed on Naughton Unit 3

The baseline NO_X concentration of 0.50 lb/mmBtu was established from Naughton Unit 3 performance historian ("PI") data and confirmed with continuous emissions data and flue gas testing.

PM emissions control technologies evaluated for Naughton Unit 3 include: (1) install a stand-alone baghouse to replace the existing ESP; (2) install a polishing fabric filter (Compact Hybrid Particulate Collector or ("COHPAC")) to operate in series with the existing ESP; (3) rebuild the existing ESP; and (4) replace the existing ESP with a Reversing Gas Fabric Filter ("RGFF"), which is a PM cleaning device currently not often selected for use in steam electric plants.

Feasible technical alternatives to meet a PM emissions compliance limit of 0.015 lb/mmBtu are: (1) install a polishing baghouse and operate it in series with a rebuilt ESP; and (2) install a stand-alone baghouse. The *Design of Replacement Baghouse PacifiCorp Naughton 3* study established initial capital costs in 2006 dollars for these two alternatives.

The *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Firing Fuel Heat Input* reported that the unit can be converted from the current coal firing configuration and made capable to operate at full load on 100% natural gas without significant boiler equipment or pressure part modifications. NOx emissions of approximately 0.09 to 0.12 lb/mmBtu were predicted with natural gas firing, consequently indicating it would be necessary to install a post-combustion SNCR process or other post-combustion NOx control process if a NOx emissions limit of approximately 0.08 lb/mmBtu is required. An alternative FGR was proposed instead of adding a post-combustion NOx control system. The FGR can simultaneously achieve the desired NOx emissions limit at 0.08 lb/mmBtu while also achieving design steam temperatures more easily and over a broader load range. Alstom offered an opinion that potential furnace modifications that include FGR and or waterwall refractory alternatives would provide greater flexibility for NOx and carbon monoxide ("CO") control when firing 100% natural gas, and would be necessary from a performance standpoint if the boiler were to be operated at low loads.

The *Naughton Unit 3 Engineering Study to Evaluate 100% Gas Fuel Input Including Evaluation of Flue Gas Recirculation and Low Load Operation* reported that Naughton Unit 3 can be converted from the current coal firing configuration and made capable to operate at full load on 100% natural gas without significant boiler or pressure part modifications. The addition of a FGR is required to mitigate steam temperature reductions when attempting to attain required NOx emissions at full load. A FGR is also required to maintain high final reheat steam temperatures at a low load of approximately 85 MW. Alstom reported an FGR operated at about 20% FGR at full load, operated in conjunction with Alstom's recommended natural gas firing system and the existing SOFA system, is predicted to result in a NOx emissions range of 0.06 to 0.09 lb/mmBtu and a CO emissions rate at less than 0.15 lb/mmBtu.

Beyond the eight studies discussed above, The EPSCO International, Inc., *Phase III Recommendations* study of the Hunter and Huntington electrostatic precipitators (ESP) was used as the basis for the decision to convert the Hunter Unit 1 ESP to a baghouse. The decision making process began when the same type of conversion was made at Huntington Unit 2 (2004-2006). The ESP at Hunter Unit 1 and Unit 2 and Huntington Unit 1 and Unit 2 are identical and in 2003 it had become apparent that the ESP's were having operational difficulties. EPSCO International, Inc. was hired to study the situation, identify options and make recommendations for the Huntington and Hunter units. The EPSCO report titled *Phase III Recommendations* was published in November 2003.