LG&E/KU – Mill Creek Station

Phase II Air Quality Control Study

Operations and Maintenance Cost Estimate

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1.0 Operations and Maintenance Cost Estimate

The levelized annual incremental Operations and Maintenance (O&M) cost estimates for the LG&E/KU Mill Creek Station Phase II Air Quality Control Study were derived from proprietary Black & Veatch O&M estimating tools and representative estimates for similar projects. Costs were based on vendor estimates and recommendations; estimated performance information; typical costs for materials, supplies, consumables and chemicals; and input from LG&E/KU for existing plant staffing and labor rates. Black & Veatch has summarized these costs into two primary categories: fixed costs and variable costs. Fixed costs, expressed as dollars per unit of net capacity per year ($/kW-yr), do not vary directly with plant power generation and consist primarily of wages and wage-related overheads for the permanent plant staff and routine equipment maintenance. This is in contrast to the variable costs, expressed as dollars per unit of net generation ($/MWh), which tend to vary in nearly direct proportion to the output of the unit. Variable O&M includes costs associated with ash and Wet Flue Gas Desulfurization (WFGD) byproduct disposal, chemicals, reagents, utilities, and other consumables.

An electricity cost due to increased plant auxiliary power was estimated by Black & Veatch with input from LG&E/KU for the cost per unit of generation in 2011. The cost of lost revenue due to increased auxiliary power requirements is not included in the total fixed or variable O&M cost, but is listed separately at the bottom of Table 1-2.

Fuel costs are determined separately and not included in either fixed or variable O&M costs.

1.1 Fixed Costs

The major element in the estimate of incremental fixed O&M is the cost of wages for the additional labor to staff the facility. Increased staffing was estimated for the plant as a whole, not on an individual unit basis, with the understanding that there is one common control room for all four units. It was estimated that the plant would require one additional operator per shift to support the additional Air Quality Control (AQC) equipment at the site. Mill Creek currently has four distinct operating crews which would result in a total of 4 additional operators. It was also estimated that the plant would need additional maintenance support at the site. The maintenance craft personnel would consist of a total of two mechanical maintenance personnel and two instrument and control (I&C) technicians in order to ensure the reliability of the additional plant systems.

Table 1-1 shows the estimated incremental staffing plan and associated salaries. The salaries for each added position were based on an average rate of $63.89/hour and

2,080 hours per year. It was understood that the rate of $63.89/hour, provided by LG&E/KU, is a fully-loaded labor rate.

Other incremental fixed O&M costs include routine maintenance for the additional AQC equipment on each unit. The routine maintenance costs for the ash handling systems for all four units were increased based on the added equipment and additional byproduct being captured. Units 1 and 2, where a Pulse Jet Fabric Filter (PJFF) is replacing a Cold-side Electrostatic Precipitator (CS-ESP), considered the reduction in costs of the CS-ESP ash handling equipment. Unit 1 will utilize the existing fly ash handling system while Unit 2 will have its own separate fly ash handling system. Units 3 and 4 will each have a separate fly ash handling system for waste ash that is collected in the PJFF and sellable ash that is collected in the CS-ESPs and existing system. The incremental routine maintenance costs for the particulate control systems on Units 1 and 2 were determined by including maintenance expenses for the PJFF system while subtracting the maintenance expenses for the CS-ESP for each Unit. The average annual CS-ESP maintenance expenses for Units 1 and 2 were estimated using a historic Mill Creek plant budget from 2001-2011 and then pro-rating the total plant expenses for each unit based on gross capacity.

On Units 1 and 2 new ID fans with Variable Frequency Drives (VFD) are replacing existing ID fans and booster fans with hydraulic couplings while for Units 3 and 4 new booster fans with VFDs are supplementing the existing ID fans with hydraulic couplings, resulting in the same number of overall fans at the plant. Based on previous Black & Veatch studies, it is estimated that the maintenance cost for centrifugal fans with a hydraulic coupling versus centrifugal fans with a VFD are similar. As a result it was estimated that the difference in annual maintenance cost for the ID and booster fans at the Mill Creek plant would be negligible.

The estimate of annual fixed O&M costs in 2011 US $/kW-yr is shown in Table 1-2.

1.2 Variable Costs

The major elements of the expected incremental variable costs include ash and WFGD byproduct disposal, reagents, and other consumables. Ash and WFGD byproduct disposal costs include the additional byproduct being generated due to added AQC equipment and increased limestone consumption. Fly ash quantities currently sold or given away were provided by LG&E/KU on a plant basis and were not available on a unit by unit basis. Black & Veatch verified that this amount, to be collected in the Unit 3 and 4 CS-ESPs, will be available to be sold or given away in the new AQC configuration; therefore, it was assumed that the same amount of fly ash that is currently being sold or given away will continue to be sold or given away. The actual increases in ash and

WFGD byproduct disposal were not able to be determined on a unit basis, but the overall increase in ash and WFGD byproduct disposal for the plant were calculated.

Reagents and other consumables costs are based upon unit price input from LG&E/KU to the extent available, selected vendors, and Black & Veatch's past project experience for the selected technology, given the expected fuel constituents and the respective emissions limits.

The estimate of annual variable O&M costs in 2011 US $/MWh is included in Table 1-2. The total net generation (in MWh) is based on the estimated capacity factor and rated net winter capacity for each respective unit.

Variable O&M costs are based on the following assumptions:

- Annual reagent and consumables usage and ash and WFGD byproduct generation are based on full load unit operation and each unit's respective capacity factor
  - Unit 1: 68.00%
  - Unit 2: 70.00%
  - Unit 3: 75.00%
  - Unit 4: 75.00%
- Ash and WFGD byproduct waste disposal cost is $15/ton
- Limestone cost is $7.54/ton
- Pulse jet fabric filter bag replacement cost is $100/bag
- Pulse jet fabric filter cage replacement cost is $50/cage
- Pulse jet fabric filter bags and cages are replaced every three years
- Ammonia cost for SCR is $530.03/ton
- SCR catalyst replacement cost is $6,500/$m^3$
- SCR catalyst is replaced every 16,000 hours
- SCR grid tuning and testing is performed every two years at a cost of $100K per Unit
- Halogenated PAC cost is $1.10/lb
- Trona cost is $195/ton
- Changes in revenue from ash and gypsum sales were not considered
- Incremental water usage, water disposal, and water treatment costs are considered to be negligible

The incremental auxiliary power increase for each unit was estimated by Black & Veatch while the auxiliary power cost for each unit was provided by LG&E/KU. Incremental auxiliary power use and costs are listed in Appendix A.

Table 1-1. Incremental O&M Staffing Plan and Labor Expenses

	Per Shift	Shifts	Total	Annual Base Wages[1]	Over Time %	Payroll	Burden %	Total Annual Expense
OPERATIONS								
Operator	1	4	4	$132,891	0	$531,565	0	$531,565
							Operations Subtotal	**$531,565**
MAINTENANCE								
Mechanic	2	1	2	$132,891	0	$265,782	0	$265,782
I&E Technician	2	1	2	$132,891	0	$265,782	0	$265,782
							Maintenance Subtotal	**$531,565**
	Total Staff		**8**			**Grand Total Annual Labor Expenses**		**$1,063,130**

Notes:
1. Fully loaded labor rate.

Table 1-2. Summary of Annual Incremental Fixed and Variable O&M Costs

(all costs in $1000)

	Unit 1	Unit 2	Unit 3	Unit 4	Total Plant
Labor[1]					
Operations	$133	$133	$133	$133	$532
Maintenance	$133	$133	$133	$133	$532
Labor Subtotal	**$266**	**$266**	**$266**	**$266**	**$1,063**
Maintenance					
Ash Handling System	$14	$74	$92	$110	$289
SCR & Associated Systems	$29	$29	$0	$0	$59
Particulate Control System (PJFF)	$7	$7	$44	$52	$110
PAC Injection System	$13	$13	$13	$13	$52
Trona Injection System	$35	$35	$35	$35	$140
Maintenance Subtotal	**$98**	**$159**	**$183**	**$209**	**$649**
TOTAL FIXED COSTS	**$364**	**$425**	**$449**	**$475**	**$1,712**
Ash/WFGD byproduct Disposal[2]	$198	$210	$534	$561	$1,504
Limestone Usage	$8	$8	$79	$72	$167
PJFF Bag & Cage Replacement	$464	$464	$552	$656	$2,135
SCR (Ammonia)	$357	$372	$0	$0	$729
SCR Catalyst Replacement	$429	$441	$0	$0	$870
SCR Grid Tuning and Testing	$50	$50	$0	$0	$100
Mercury Control (PAC Injection)	$5,133	$5,518	$7,097	$8,643	$26,391
SO_3 Control (Trona Injection)	$2,237	$2,364	$3,220	$3,918	$11,739
Neural Network Support	$50	$50	$50	$50	$200
TOTAL VARIABLE COSTS	**$8,925**	**$9,477**	**$11,532**	**$13,900**	**$43,834**
Winter Net Capacity (MW)	**303**	**299**	**397**	**492**	**1,491**
Net Generation (MWh)	**1,805,609**	**1,833,468**	**2,608,290**	**3,232,440**	**9,479,807**
Fixed Costs, $/kW-yr	**$1.20**	**$1.42**	**$1.13**	**$0.97**	**$1.15**
Variable Costs, $/MWh	**$4.94**	**$5.17**	**$4.42**	**$4.30**	**$4.62**
ELECTRICITY TOTAL COST	**$462**	**$510**	**$968**	**$1,631**	**$3,571**

Notes:

1. Staffing and associated costs shown for total plant, but divided up equally among the four units.
2. Current annual fly ash quantities sold or given away were not provided on a unit basis. All fly ash to be sold or given away shall come from Units 3 & 4. Therefore, changes in ash/byproduct disposal costs do not reflect actual increases for each unit. Ash/WFGD byproduct disposal costs shown for total plant should be used.

Appendix A
Auxiliary Power Costs

The table below is a summary of the Mill Creek differential auxiliary power costs.

Mill Creek Differential Auxiliary Power Costs					
Units	**Differential Aux**	Capacity	**Annual Diff.**	Aux Power	**Annual Aux**
	Operating (kW)	Factor	**Aux (MWh)**	Cost ($/MWh)	**Power Cost**
Unit 1	**3,595**	68%	**21,413**	$21.56	**$461,669**
Unit 2	**3,835**	70%	**23,519**	$21.69	**$510,120**
Unit 3	**6,320**	75%	**41,520**	$23.31	**$967,839**
Unit 4	**11,110**	75%	**72,990**	$22.35	**$1,631,326**
Total	**24,859**		**159,442**		**$3,570,954**

The tables below are a detailed breakdown of the differential auxiliary power use for each Mill Creek unit.

Mill Creek Unit 1					
List of Items	**Normal Quantity Operating**	**Normal Operating HP**	**Normal Operating Time**	**Normal Operating kW**	**Total Operating kW**
ID FANS					
ID FANS	2.0	5400.0	24.0	4739.3	9,479
MISC ID FAN LOADS (lube oil pumps, heater, cooling fans)	2.0	15.0	24.0	12.0	24
CURRENT EXISTING ID AND BOOSTER FANS	2.0	-3800.0	24.0	-3335.1	-6,670
EXISTING MISC ID AND BOOSTER FAN LOADS CANCEL OUT W/ NEW FAN	2.0	-15.0	24.0	-12.0	-24
ID FAN SUBTOTAL					***2,808***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***397***
EXISTING ELECTROSTATIC PRECIPITATOR (ESP)					
CURRENT ESP	1.0		24.0	-500.0	-500
ESP SUBTOTAL					***-500***
SELECTIVE CATALYTIC REDUCTION (SCR)					
RILEY POWER INC SCR SYSTEM	1.0		24.0	200.0	200
SCR SUBTOTAL					***200***
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC INJECTION SUBTOTAL					***44***
SORBENT INJECTION					
SORBENT INJECTION SUBTOTAL					***59***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***183***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***402***
TOTAL					**3,595**

Notes:

1	Motor Efficiencies were assumed at 93% except for compressors and ID fan drivers including VFDs which were assumed at 85%

Mill Creek Unit 2					
List of Items	**Normal Quantity**	**Normal**	**Normal**	**Normal**	**Total**
	Operating	**Operating HP**	**Operating Time**	**Operating kW**	**Operating kW**
ID FANS					
ID FANS	2.0	5400.0	24.0	4739.3	9,479
MISC ID FAN LOADS (lube oil pumps, heater, cooling fans)	2.0	16.0	24.0	12.8	26
CURRENT EXISTING ID AND BOOSTER FANS	2.0	-3800.0	24.0	-3335.1	-6,670
EXISTING MISC ID AND BOOSTER FAN LOADS CANCEL OUT W/ NEW FAN	2.0	-16.0	24.0	-12.8	-26
ID FAN SUBTOTAL					***2,808***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***638***
EXISTING ELECTROSTATIC PRECIPITATOR (ESP)					
CURRENT ESP	1.0		24.0	-500.0	-500
ESP SUBTOTAL					***-500***
SELECTIVE CATALYTIC REDUCTION (SCR)					
SCR SUBTOTAL					***200***
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC INJECTION SUBTOTAL					***44***
SORBENT INJECTION					
SORBENT INJECTION SUBTOTAL					***59***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***183***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***402***
TOTAL					**3,835**

Notes:

1	Motor Efficiencies were assumed at 93% except for compressors and ID fan drivers including VFDs which were assumed at 85%

Mill Creek Unit 3					
List of Items	**Normal Quantity**	**Normal**	**Normal**	**Normal**	**Total**
	Operating	**Operating HP**	**Operating Time**	**Operating kW**	**Operating kW**
BOOSTER FANS					
BOOSTER FANS	2.0	3500.0	24.0	3071.8	6,144
MISC BOOSTER FAN LOADS (lube oil pumps, heater, cooling fans)	2.0	14.0	24.0	11.2	22
CURRENT EXISTING ID FANS	2.0	-6100.0	24.0	-5353.6	-10,707
FUTURE EXISTING ID FANS	2.0	4500.0	24.0	3949.4	7,899
MISC ID FAN LOADS CANCEL OUT	2.0	0.0	24.0	0.0	0
BOOSTER FAN SUBTOTAL					***3,358***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***773***
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC INJECTION SUBTOTAL					***44***
SORBENT INJECTION					
SORBENT INJECTION SUBTOTAL					***59***
WET FLUE GAS DESULFURIZATION (WFGD)					
CURRENT UNIT 3 SCRUBBER	1.0		24.0	-4000.0	-4,000
CURRENT UNIT 4 SCRUBBER	1.0		24.0	5500.0	5,500
ESP SUBTOTAL					***1,500***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***183***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***402***
TOTAL					**6,320**

Notes:

1	Motor Efficiencies were assumed at 93% except for compressors and ID fan drivers including VFDs which were assumed at 85%

Mill Creek Unit 4					
List of Items	**Normal Quantity Operating**	**Normal Operating HP**	**Normal Operating Time**	**Normal Operating kW**	**Total Operating kW**
BOOSTER FANS					
BOOSTER FANS	2.0	3700.0	24.0	3247.3	6,495
MISC BOOSTER FAN LOADS (lube oil pumps, heater, cooling fans)	2.0	15.0	24.0	12.0	24
CURRENT EXISTING ID FANS	2.0	-7500.0	24.0	-6582.4	-13,165
FUTURE EXISTING ID FANS	2.0	5500.0	24.0	4827.1	9,654
MISC ID FAN LOADS CANCEL OUT	2.0	0.0	24.0	0.0	0
BOOSTER FAN SUBTOTAL					***3,008***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***1,101***
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC INJECTION SUBTOTAL					***44***
SORBENT INJECTION					
SORBENT INJECTION SUBTOTAL					***59***
WET FLUE GAS DESULFURIZATION (WFGD)					
REACTION TANK AGITATORS	4.0	75.0	24.0	60.2	241
RECYCLE PUMPS	5.0	2000.0	24.0	1604.3	8,022
SLURRY BLEED PUMPS	1.0	175.0	24.0	140.4	140
OXIDATION AIR BLOWERS	1.0	3000.0	24.0	2406.5	2,406
OXIDATION AIR BLOWER INLET GUIDE VANES	1.0	3.0	24.0	2.4	2
OXIDATION AIR LUBE OIL PUMPS	2.0	25.0	24.0	20.1	40
OXIDATION AIR BLOWER BLOWOFF VALVE MOTORS	1.0	3.0	24.0	2.4	2
OXIDATION AIR BLOWER DISCHARGE DIFFUSER VANE MOTORS	1.0	3.0	24.0	2.4	2
MIST ELIMINATOR WASH WATER PUMPS	1.0	115.0	24.0	92.2	92
ABSORBER AREA SUMP PUMPS	1.0	30.0	1.0	24.1	1
ABSORBER AREA SUMP AGITATORS	1.0	8.5	24.0	6.8	7
CHLORINE BLEED PUMPS	1.0	20.0	24.0	16.0	16
HYDROCYCLONE UNDERFLOW TRANSFER TANK AGITATOR	1.0	75.0	24.0	60.2	60
HYDROCYCLONE UNDERFLOW TRANSFER PUMPS	1.0	175.0	24.0	140.4	140
CURRENT EXISTING UNIT 4 SCRUBBER	1.0		24.0	-5500.0	-5,500
WFGD SUBTOTAL					***5,673***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***620***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***604***
TOTAL					**11,110**

Notes:

1	Motor Efficiencies were assumed at 93% except for compressors and ID fan drivers including VFDs which were assumed at 85%