LG&E/KU – E.W. Brown 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 E.W. Brown 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 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.

Incremental fixed and variable O&M costs developed by Black & Veatch do not include a cost differential for the Selective Catalytic Reduction (SCR) and Sorbent Injection systems already planned in 2012 for Unit 3. Fuel costs are determined separately and not included in either fixed or variable O&M costs.

1.1 Fixed Costs

A 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. 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. The Brown station 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 one mechanical maintenance person and one instrument and control (I&C) technician 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 $59.29/hour and

2,080 hours per year. It was understood that the rate of $59.29/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. A Pulse Jet Fabric Filter (PJFF) is being added to each unit while taking each Cold-side Dry Electrostatic Precipitator (CS-DESP) out of service. Based on the Black & Veatch projected routine maintenance costs of the PJFF compared to the historic maintenance costs provided by the Brown station for the CS-ESP, it was estimated that the overall change in maintenance costs for the particulate control systems would be negligible. The major difference in O&M costs for the PJFF versus the CS-DESP is the bag and cage replacement which is covered under the variable costs. Routine maintenance costs for the ash handling systems for all three units were increased as a result of the conversion from a wet to dry fly ash handling system and additional byproduct being captured. The expected increase in maintenance costs associated with a dry ash handling system was based on vendor information for power plants that have undergone similar ash handling system conversions. It is expected that all fly ash collected will be considered waste and will be sent to the on-site landfill for disposal.

It was estimated that there will be a slight maintenance cost savings by replacing the two existing ID fans with one new larger ID fan for Unit 2. For this level of study the savings is considered to be negligible and a maintenance credit was not applied to the O&M estimate. Additional maintenance costs were added to cover a new Powdered Activated Carbon (PAC) injection system on all three units and new sorbent (lime or trona) injection system on Units 1 and 2 as well as a Selective Catalytic Reduction (SCR) system on Units 1 and 2. With the addition of an SCR system on Units 1 and 2 there will be several changes to the combustion air system including the air preheat system, air heaters and FD fans. It is expected that there will be a slight reduction in maintenance costs for the future combustion air system. For the purpose of this study the change in maintenance costs for the existing combustion air system versus the future combustion air system is considered to be negligible and a credit was not applied to the O&M estimate.

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 disposal, reagents, and other consumables. Ash disposal costs include the additional byproduct being generated due to added AQC equipment. It was assumed that all existing fly ash collected as well as the additional fly ash being generated and collected at the facility will be sent to the on-site landfill for disposal.

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 provided and rated net capacity for each respective unit.

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

- Annual reagent and consumables usage and ash generation are based on full load unit operation and each unit's respective capacity factor
  - Unit 1: 44.00%
  - Unit 2: 62.00%
  - Unit 3: 57.00%
- Ash disposal cost is $15/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/ton
- SCR catalyst replacement cost is $6,500/$m^3$
- SCR catalyst is replaced every 16,000 operating hours
- SCR grid tuning and slip testing is performed approximately every 2 years at a cost of $100K per unit
- Halogenated PAC cost is $1.10/lb
- Trona cost is $200/ton
- 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	1	1	1	$132,891	0	$132,891	0	$132,891
I&E Technician	1	1	1	$132,891	0	$132,891	0	$132,891
						Maintenance Subtotal		**$265,782**
	Total Staff		**6**	**Grand Total Annual Labor Expenses**				**$797,347**

Notes:
1. Based on fully loaded labor rate.

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

(all costs in $1000)

	Unit 1	Unit 2	Unit 3	Total Plant
Labor[1]				
Operations	$177	$177	$177	$532
Maintenance	$89	$89	$89	$266
Labor Subtotal	**$266**	**$266**	**$266**	**$797**
Maintenance				
Ash Handling System	$54	$55	$103	$212
SCR & Associated Systems	$13	$19	$0	$32
PAC Injection System	$14	$14	$14	$42
Sorbent Injection System (Trona)	$30	$30	$0	$60
Maintenance Subtotal	**$110**	**$118**	**$117**	**$346**
TOTAL FIXED COSTS	**$376**	**$384**	**$383**	**$1,143**
Ash Disposal	$42	$86	$51	$180
PJFF Bag & Cage Replacement	$159	$222	$552	$933
SCR (Ammonia)	$116	$265	$0	$381
SCR Catalyst Replacement	$139	$317	$0	$456
SCR Grid Tuning and Testing	$50	$50	$0	$100
Mercury Control (PAC Injection)	$1,179	$2,354	$5,509	$9,042
SO_3 Control (Sorbent Injection)	$461	$1,083	$0	$1,544
Neural Network Support	$50	$50	$50	$150
TOTAL VARIABLE COSTS[2]	**$2,196**	**$4,427**	**$6,162**	**$15,247**
Net Capacity (MW)[3]	**102**	**169**	**433**	**704**
Net Generation (MWh)	**393,149**	**917,873**	**2,162,056**	**3,473,077**
Fixed Costs, $/kW-yr	**$3.69**	**$2.27**	**$0.89**	**$1.62**
Variable Costs, $/MWh	**$5.58**	**$4.82**	**$2.85**	**$4.39**
ELECTRICITY TOTAL COST	**$218**	**$687**	**$183**	**$1,088**

Notes:

1. Staffing and associated costs shown for total plant, but divided up equally among the three units.
2. Variable Costs in this table do not include Auxiliary Power Costs.
3. Net capacities are from "Appendix B Unit Specific Data" of the Phase I Air Quality Control Technology Cost Assessment report.

Appendix A
Auxiliary Power Costs

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

Brown 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	**1,328**	44%	**5,120**	$42.66	**$218,411**
Unit 2	**3,467**	62%	**18,833**	$36.46	**$686,638**
Unit 3	**1,010**	57%	**5,041**	$36.24	**$182,701**
Total	**5,805**		**28,994**		**$1,087,750**

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

Brown Units 1 & 2					
List of Items	**Normal Quantity Operating**	**Normal Operating HP**	**Normal Operating Time**	**Normal Operating kW**	**Total Operating kW**
UNIT 1					
FD and ID FANS					
FD FAN	1.0	700.0	24.0	614.4	614
CURRENT EXISTING FD FANS	2.0	-280.0	24.0	-245.7	-491
MISC FD FAN LOADS (lube oil pumps, heater, cooling fans)	1.0	15.0	24.0	12.0	12
APPROX. MISC EXISTING FD FAN LOADS	2.0	-15.0	24.0	-12.0	-24
CURRENT EXISTING ID FANS	1.0	-4100.0	24.0	-3598.4	-3,598
FUTURE EXISTING ID FANS	1.0	4400.0	24.0	3861.6	3,862
MISC ID FAN LOADS CANCEL OUT	1.0	0.0	24.0	0.0	0
FANS SUBTOTAL					***374***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***478***
AIR HEATER					
FUTURE & EXISTING DRIVE MOTORS CANCEL OUT	1.0	0.0	24.0	0.0	0
AIR HEATER SUBTOTAL					***0***
AIR PREHEAT COIL					
EXISTING RECIRCULATION AIR FANS	2.0	-45.0	24.0	-36.1	-72
NEW HOT WATER PUMPS	1.0	28.0	24.0	22.5	22
AIR PREHEAT COIL SUBTOTAL					***-72***
SELECTIVE CATALYTIC REDUCTION (SCR)					
SCR SUBTOTAL					***200***
EXISTING ELECTROSTATIC PRECIPITATOR (ESP)					
CURRENT ESP	1.0		24.0	-125.0	-125
CURRENT ASH SLUICE PUMPS	1.0	-200.0	24.0	-160.4	-160
ESP SUBTOTAL					***-285***
UNIT 1 SUBTOTAL					**694**
1	Motor Efficiencies were assumed at 93% except for compressors and ID/FD fan drivers including VFDs which were assumed at 85%				

Brown Units 1 & 2					
List of Items	**Normal Quantity Operating**	**Normal Operating HP**	**Normal Operating Time**	**Normal Operating kW**	**Total Operating kW**
UNIT 2					
FD and ID FANS					
FD FAN	1.0	1200.0	24.0	1053.2	1,053
CURRENT EXISTING FD FANS	2.0	-430.0	24.0	-377.4	-755
MISC FD FAN LOADS (lube oil pumps, heater, cooling fans)	1.0	16.0	24.0	12.8	13
APPROX. MISC EXISTING FD FAN LOADS	2.0	-16.0	24.0	-12.8	-26
ID FAN	1.0	5600.0	24.0	4914.8	4,915
CURRENT EXISTING ID FANS	2.0	-1500.0	24.0	-1316.5	-2,633
MISC ID FAN LOADS (lube oil pumps, heater, cooling fans)	1.0	16.0	24.0	12.8	13
APPROX. MISC EXISTING ID FAN LOADS	2.0	-16.0	24.0	-12.8	-26
FANS SUBTOTAL					***2,555***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***530***
AIR HEATER					
FUTURE & EXISTING DRIVE MOTORS CANCEL OUT	1.0	0.0	24.0	0.0	0
AIR HEATER SUBTOTAL					***0***
HOT WATER AIR PREHEAT COIL					
FUTURE & EXISTING PUMPS CANCEL OUT	1.0	0.0	24.0	0.0	0
HOT WATER AIR PREHEAT COIL SUBTOTAL					***0***
SELECTIVE CATALYTIC REDUCTION (SCR)					
SCR SUBTOTAL					***200***
EXISTING ELECTROSTATIC PRECIPITATOR (ESP)					
CURRENT ESP	1.0		24.0	-250.0	-250
CURRENT ASH SLUICE PUMPS	1.0	-250.0	24.0	-200.5	-201
ESP SUBTOTAL					***-451***
UNIT 2 SUBTOTAL					**2834**

Notes:

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

Brown Units 1 & 2					
List of Items	**Normal Quantity Operating**	**Normal Operating HP**	**Normal Operating Time**	**Normal Operating kW**	**Total Operating kW**
COMMON FOR UNIT 1 & 2					
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC BLOWER	2.0	11.5	24.0	9.2	18
PAC CONVEYING AIR BLOWER (Secondary)	0.0	11.5	24.0	9.2	0
PAC FEEDER HOPPER	2.0	1.0	24.0	0.8	2
PAC ROTARY FEEDER VALVE	2.0	0.5	24.0	0.4	1
PAC SKIRT HVAC UNIT HEATER	2.0		24.0	10.0	20
PAC SKIRT HVAC VENTILATION FAN	2.0	2.0	24.0	1.6	3
PAC HOPPER VIBRATORS	3.0	0.2	8.0	0.1	0.1
PAC INJECTION SUBTOTAL					***44***
SORBENT INJECTION					
SORBENT INJECTION SUBTOTAL					***59***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***360***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***804***
COMMON UNIT 1&2 SUBTOTAL					**1268**
TOTAL					**4,796**

Notes:

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

Brown Unit 3					
List of Items	**Normal Quantity**	**Normal**	**Normal**	**Normal**	**Total**
	Operating	**Operating HP**	**Operating Time**	**Operating kW**	**Operating kW**
ID FANS					
CURRENT (Note 2) AND FUTURE EXISTING ID FAN LOADS CANCEL OUT	0.0	0.0	24.0	0.0	0
ID FAN SUBTOTAL					***0***
PULSE JET FABRIC FILTER (PJFF)					
PJFF SUBTOTAL					***786***
EXISTING ELECTROSTATIC PRECIPITATOR (ESP)					
CURRENT ESP	1.0		24.0	-550.0	-550
CURRENT ASH SLUICE PUMPS	1.0	-250.0	24.0	-200.5	-201
ESP SUBTOTAL					***-751***
POWDER ACTIVATED CARBON (PAC) INJECTION					
PAC INJECTION SUBTOTAL					***44***
ENCLOSURE LOADS					
ENCLOSURE LOADS SUBTOTAL					***360***
STATION FLY ASH HANDLING SYSTEM					
STATION FLY ASH HANDLING SYSTEM SUBTOTAL					***168***
MISCELLANEOUS LOADS					
MISC LOADS SUBTOTAL					***402***
TOTAL					**1,010**

Notes:

1	Motor Efficiencies were assumed at 93% except for compressors and ID fan drivers including VFDs which were assumed at 85%
2	Current existing ID Fan horsepowers account for operation with the planned SCR online.