Conversion of Mill Creek 1&2 and Brown 3 to Natural Gas Fired

SUMMARY

Cost estimates to convert Mill Creek (MC) units 1 and 2 and E.W. Brown (EWB) unit 3 to natural gas as the primary fuel are based on several studies performed over the last five years related to, but not intended for this specific purpose. The anticipated costs for conversion of EWB are based on a more detailed analysis than MC, and the MC estimates are influenced by the EWB study.

As filed with the Kentucky Public Service Commission, the conversion of Big Rivers Electric Corporation's (BREC) Green Station Units 1 and 2 is estimated at $45.3 million for a total output capability of 414 MWs. This equates to $109 per KW installed.

The conversion of MC 1&2 is conservatively estimated at approximately $69 million for a total output capability of 617 MWs. This equates to $112 per KW installed. The cost for EWB is considerably more at $237 per KW installed or approximately $100 million for 424 MWs of capability with the difference due to the pipeline modifications needed to supply additional capacity at the respective facilities. Excluding pipeline costs, MC and EWB are expected to be approximately $95/KW and $92/KW respectively. The pipeline infrastructure could support conversion to a combined cycle gas turbine at either site in the future. The capital costs do not include modifications to maintain the current generating capability of the units, and the output capacity includes a reduction approaching 10%.

O&M savings are estimated at $7.5 to $9 million annually post conversion based on eliminating coal handling and pollution control expenses. These estimates were based on a high-level review by plant personnel at EWB and MC.

The projected heat rate of a natural gas conversion would be higher (less efficient) than the average heat rate for the LKE simple cycle gas turbine fleet. The fuel cost would be almost double that of Cane Run 7. This evaluation did not include any impacts from potential carbon constraints.

Emissions of particulate, metals, SO_2, and NO_x will decrease when a unit is converted from coal to gas. However, CO and VOCs would increase, requiring environmental permitting and additional pollution controls which were not included. NOx would likely remain an issue in Jefferson County and may potentially require continued seasonal reduced operation of the MC units. A boiler study would be required to obtain better estimates of NOx emissions for MC1 and 2. The existing SCR at EWB could remain in service for additional NOx control.

The project timeline for conversion is estimated at 24 months exclusive of permits.

CAPITAL COSTS

Mill Creek 1, 2 and Brown 3 Gas Conversion Cost Estimate			
	2020 Dollars $	2017 Dollars $	
	BREC Green 1&2	Mill Creek 1&2	Brown 3
Unit(s) Capacity on Natural Gas	414	617	424
Total Capital Cost of Unit Conversion[1]	$38,300,000	$58,532,199	$38,993,025
Total Capital Cost of Gas Pipeline[2] (Range of Options for BR3)	$7,000,000	$10,409,084	$61,435,808
Total Estimated Capital Cost	$45,300,000	$68,941,284	$100,428,833
Project Cost per KW installed	$109	$112	$237

1 B&V Study, +/-30%, used to estimate MC costs
2 EN Engineering Study, +/-20%

BROWN UNIT 3

GAS SUPPLY – Replace existing pipeline with large capacity and re-route

Modification of the existing natural gas pipeline to the Brown Station is required to support conversion of the coal units to gas. The 2017 B&V analysis included supply for all three Brown units. Modifications included a new 30" gas pipeline from a main line ~10 miles from the plant, a new supply line crossing the river, new high pressure regulating, metering and heating stations, new low pressure regulating, metering and heating stations, fail safe valves included.

A second cost estimate was provided by EN Engineering (ENE) which included alternative routing of the gas line and was significantly higher cost than the B&V estimate.

UNIT CONVERSION

As noted above, capital costs associated with conversion of Brown Unit 3 to natural gas were evaluated by Black & Veatch (B&V) in 2017. In addition to a larger gas pipeline, the costs included replacement of the coal burner system with gas burners, draft system upgrades, controls system upgrades, and electrical system upgrades. The pipeline costs have been adjusted to account for the work completed to date. The total installed project cost for conversion of Brown Unit 3 to natural gas is ~$100mm or $237/KW.

MILL CREEK UNITS 1 AND 2

GAS SUPPLY – New gas pipeline to nearby Texas Gas transmission line

The current gas supply to Mill Creek Station for startup fuel is sourced from an LG&E distribution line. To provide adequate gas conditions and flow rate, a new gas pipeline sourced from the Texas Gas transmission pipeline is required. In 2021 ENE developed a cost estimate for the new pipeline to service an NGCC at Mill Creek plant. The basis for Mill Creek 1&2 natural gas supply is based on the ENE estimate, plus an additional 0.5 miles of pipeline from the NGCC site to the coal plant. The total estimated cost is $10.4 million.

UNIT CONVERSION

No study of full natural gas conversion of Mill Creek Units 1 and 2 has been conducted. An estimate of gas co-firing capability has been completed by B&V as part of a 2017 NOx reduction review. This data was used along with the estimated cost of conversion for Brown 3 to estimate a project cost for Mill Creek 1 and 2. It is assumed that the units will be derated approximately 10% when burning natural gas at the same heat input as current coal operation. The above described gas pipeline cost estimate was used as the basis for cost to supply natural gas to Mill Creek 1 and 2. The resulting gas conversion cost for Mill Creek Units 1 and 2 is ~$69mm or $112 per KW.

PROJECT TIMELINE

Project timeline estimates do not include right of way or land acquisition or environmental permits.

BROWN UNIT 3

Brown Unit 3 Gas Conversion	
Activity	# Months
Gas Pipeline Engineering, Procurement, Construction	17
Generating Units Conversion to Gas, Engineering, Procurement, Construction	24

MILL CREEK UNITS 1 AND 2

Mill Creek Units 1 and 2 Gas Conversion	
Activity	# Months
Gas Pipeline Engineering, Procurement, Construction	12
Generating Units Conversion to Gas, Engineering, Procurement, Construction	No Estimate Available

O&M COSTS

Conversion from coal to natural gas will result in O&M cost savings in the following key areas:

- Elimination of coal and ash handling equipment.
- Elimination of air quality control equipment, including WFD, ESP, PJFF, DSI systems and appurtenances.
- Reduced auxiliary power requirements, particularly air and gas handling equipment.

No costs were added back in this analysis for additional environmental equipment that may be required such as CO or VOC catalyst.

Generation personnel have estimated the annual O&M cost savings resulting from conversion to natural gas. The results are provided in the table below.

Projected Annual O&M Savings Resulting from Natural Gas Conversion	
Year over Year, Based on 2022 Savings Estimates	
Brown 3 Gas Conversion Savings (000's)	$9,154
Mill Creek 1 and 2 Gas Conversion Savings (000's)	$7,673

KEY CONSIDERATIONS

EMISSIONS

Gas is a cleaner fuel than coal and as such emission of particulate, metals, SO_2, and NOx will decrease. The wet FGD and PJFF can be taken out of service. MATS will no longer apply to the gas fired units. CO and VOC emissions will increase above the NSR significance level and would require Best Available Control Technology (BACT) Analysis. Addition of CO/VOC reduction catalyst would likely be required.

Brown Unit 3

NOx: Brown will still need to meet the consent decree limit of 0.070 lb/mmbtu NOx on a 30-day rolling average. The SCR at Brown 3 will be required to ensure compliance with the NOx emissions limit. The SCR will operate at a lower removal efficiency than currently required.

CO & VOC: Brown would exceed the significance level of CO. A catalyst would be required to minimize CO emissions for BACT.

VOCs: Brown would exceed the significance level of VOC. A catalyst would be required to minimize VOC emissions for BACT.

Mill Creek Units 1 and 2

NOx: Mill Creek 1 and 2 NOx emissions would decrease when burning gas. It is unlikely that the plant would exceed a 15 tons/day limit during ozone season, given an emission rate of 0.08-0.12 lb/mmbtu form units 1 and 2 (no change to MC3&4 emissions). However, this could be an issue if the units operated above the 0.12 lb/mmbtu rate. This conclusion is based on currently projected generation for Mill Creek units.

CO: Mill Creek would exceed the significance level of CO. A catalyst would be required to minimize CO emissions for BACT.

VOCs: Mill Creek would exceed the significance level of VOC. A catalyst would be required to minimize VOC emissions for BACT. In addition, any VOC emissions increase may require a multiplier for off-set emissions in Jefferson County, depending on the attainment status at the time of the unit conversion. [1] The multiplier can range from 1.15 to 1.5, based on the area attainment status. NOx emission reductions may be used for inter-pollutant trading since ozone regulations cover both NOx and VOCs as criteria pollutants. Modelling would be required to determine the appropriate inter-pollutant trading ratio.

1) *Under NSR regulations, if an area is non-attainment (or maintenance) for a pollutant then any major construction projects require an offset that is based upon the SIP and/or non-attainment level. For Jefferson County, it is 1.15:1. There have to be 1.15 tons of VOC/NOx reduction for every 1 ton of increase (APCD Regulation 2.04). 40 CFR 51.165, 40 CFR 51 Appendix S does allow interprecursor trading (IPT) since the CAA defines ozone as the criteria pollutant and NOx and VOC are both recognized as precursors to ozone. APCD's "Options for Replacement Reductions to Offset Close of Vehicle Emissions Testing Program, in*

Jefferson County, Kentucky" laid out a methodology based upon the emission ratio of pollutants "for substitution of one pollutant for required reduction of the other pollutant." The ratio of emissions in tons per summer day were 2:1 of NOx to VOC in 2002. Thus, a reduction of 2 pounds of NOx would be equivalent to reducing 1 pound of VOC. To compensate for an increase of 1 pound of VOC, a reduction of 2 pounds of NOx could be substituted. The number would need to be updated but would likely not be greater than the 2:1 used previously. This is in addition to the offset.

PERFORMANCE

Boiler Steaming Capability

Radiant heat transfer characteristics of gas are less than those of coal, potentially lowering steaming capacity, which may be offset by increasing boiler heat input, if regulations permit. Resultant impacts to steam temperatures are dependent on boiler design. A thermal model analysis is necessary to determine any required modifications to the boiler to meet targets. If heat input to the boiler is not increased, lower steam temperatures may result in unit derates.

Plant Heat Rate and Efficiency

Boiler efficiency will be reduced due to the increase in latent heat loss resulting from the large amount of hydrogen in natural gas. Unburned carbon losses will decrease due to ease of combustion of gas. The impact to sensible heat losses and the impact to steam temperatures and exit flue gas temperature is dependent on boiler design and must be modeled. For comparison, the LKE fleet of 16 CTs range in heat rate performance from 10,034 but/nkwh (TC10) to 12,453 btu/nkwh (BR5), based on winter test results. The average winter heat rate for all CTs is 10,750 btu/nkwh.

Brown Unit 3

The B&V study modeled impacts to Brown 3 performance, summarized in the table below.

EW Brown Unit 3		
	Coal	Gas
Target Gross Turbine Generator Load, MW	448.03	448.03
Turbine Derate, MW	0	23.7
Turbine Derate, %	NA	5.3
Maximum Gross Turbine Output, MW	448.03	424.33
Boiler Efficiency, % (HHV)	87.36	84.36
Net Plant Heat Rate, Btu/kWh	10696	11086
Boler Heat Input, Mbtu/hr	4562.77	4820.68
Coal Flow Rate, ton/hr	202.57	
Natural Gas Flow Rate, kcfm		75.5
Main Steam Outlet Temperature, °F	968	916
Hot Reheat Steam Outlet Temperature, °F	997	910
Economizer Flue Gas Outlet Temperature, °F	746.5	714.8
Air Heater Flue Gas Outlet Temperature, °F	317.2	292.1

Reference Documents

Black & Veatch, 2017, Natural Gas Conversion Study, E.W. Brown Station Units 1, 2, and 3

EN Engineering, 2017, Natural Gas Transmission Pipeline Cost Estimate, E.W. Brown Station 30" Proposed Pipeline

Black & Veatch, 2017, NOx Reduction Study

Generation Engineering, 2020, Mill Creek Units 1&2 Gas Co-Firing

EN Engineering, 2021, Mill Creek Generating Station Pipeline Feed Study

Environmental Affairs, 2021, Draft Estimation of Netting for NG Conversion, PowerPoint