Chapter 6 - Appendix A

Fatal Flaw Analysis

Option	Description	Fatal Flaw
Coal	Meramec Repowering - Unit 3 Boiler Replacement and STG Rebuild	✗
Coal	Meramec Repowering - Unit 4 Boiler Replacement and STG Rebuild	✗
Coal	Meramec Repowering - Oxyfuel Coal Boiler Replacement	✗
Coal	Meramec Repowering - CFB Boiler Replacement	✗
Coal	Greenfield - USCPC	✓
Coal	Greenfield - Oxyfuel Coal with CCC	✓
Coal	Greenfield - IGCC	✓
Coal	Greenfield - Subcritical CFB	✓
Coal	Greenfield - Supercritical CFB	✓
Coal	Greenfield - Pressurized Circulating Fluidized Bed (CFB)	✗
Coal	Greenfield - Pressurized Bubbling Fluidized Bed (BFB)	✗
Coal	Greenfield - USCPC with Amine-Based Post-Combustion CCC	✓
Coal	Greenfield - Subcritical CFB with Amine-Based Post-Combustion CCC	✓
Coal	Greenfield - IGCC with Pre-Combustion CCC	✓
Coal	Efficiency Improvements to Existing Plants – Duct Draft Reductions	✓
Coal	Efficiency Improvements to Existing Plants – Condenser Back-pressure Reductions	✓
Gas	Greenfield - CCCT Amine-Based Post-Combustion CCC	✓
Gas	Greenfield - 2-on-1 501F CCCT	✓
Gas	Mexico - One GE LM6000 Sprint SCCT (5% CF)	✓
Gas	Mexico - One GE LM6000 Sprint SCCT (10% CF)	✓
Gas	Raccoon Creek - One GE 7EA SCCT (5% CF)	✓
Gas	Raccoon Creek - One GE 7EA SCCT (10% CF)	✓
Gas	Meramec Repowering - Unit 3 Boiler NG Conversion	✗
Gas	Meramec Repowering - Unit 4 Boiler NG Conversion	✗
Gas	Meramec Repowering - Unit 3 & Unit 4 STGs in Separate CCCT Conversions	✗
Gas	Meramec Repowering - Unit 3 & Unit 4 STGs in a Shared CCCT Conversion	✗
Gas	Greenfield - Molten Carbonate Fuel Cell	✓
Gas	Greenfield - Natural Gas Fueled Rankine Cycle	✗
Gas	Greenfield - Twelve Wartsila 20V34SG Simple Cycle Reciprocating Engines	✓
Gas	Greenfield - Two 501F SCCTs (5% CF)	✓
Gas	Greenfield - Two 501F SCCTs (10% CF)	✓
Gas	Greenfield – 2-on-1 Wartsila 20V34SG Combined Cycle Reciprocating Engine	✓
Gas	Greenfield – GE 7EA Cheng Cycle	✓

A high-level fatal flaw analysis was conducted as part of the first stage of the supply-side selection analysis. Options that did not pass the high-level fatal flaw analysis consist of those options that could not be reasonably developed or implemented by Ameren Missouri; options that passed were considered preliminary candidate resource options.[1]

In general for the coal & natural gas options, the “Greenfield” options were selected to represent the technology because additional studies would need to be implemented for specific locations. For example, the Greenfield-USCPC passed and the Rush Island-USCPC did not pass the first stage of the high-level fatal flaw analysis. Note: The Meramec coal and gas options were eliminated from the analysis and will be evaluated as part of the integration analysis.

Below are details for several options that did not pass the high-level fatal flaw analysis.

This fatal flaw analysis did not take into account potential carbon dioxide (CO_2) regulations that might result from the White House Climate Action Plan. The President directed the EPA to propose rules for modified, reconstructed and existing power plants no later than June 1, 2014 with finalization of the rule no later than June 1, 2015. The EPA published proposed rules on June 2, 2014 in response to the President’s directive. The EPA is taking comments on the proposed rule for existing sources until December 1, 2014. EPA continues to indicate it plans to finalize the existing source rule by June 1, 2015.

Meramec Repowering – Unit 3 Boiler NG Conversion (Option A08.1)

This option is not feasible because it is likely that the unit would have a low capacity factor (i.e., cycling service) which would potentially cause equipment/operational issues due to the age of the plant.

The following scope of work applies to the Meramec Unit 3 and 4 options in which the boilers would be converted to burn natural gas:

1. Burner replacement.
2. Reheater modifications.
3. Superheater modifications.
4. Desuperheater spray modifications.
5. Air heater modifications.
6. Boiler controls modifications.

[1] 4 CSR 240-22.040(2); 4 CSR 240-22.040(2)(C); 4 CSR 240-22.040(2)(C)2

Additional work may include:

- Installation of new natural gas supply regulating stations, piping, and valves in the boiler house
- Primary air isolation modifications

Meramec Repowering – Unit 4 Boiler NG Conversion (Option A08.2)

This option is not feasible for the same reasons that Option A08.1 is not feasible.

Meramec Repowering – Unit 3 & Unit 4 STGs in Separate CCCT Conversions (Option A10)

This option is not feasible because of the age of the turbine and heat cycle equipment and transmission limitations. The electrical output from the current units is roughly 850 MW. If the Unit 3 and 4 steam turbine generators (STGs) were converted for use in separate combined cycles, the Unit 3 block would produce an estimated net output of 600 to 700 MW, and the Unit 4 block would produce an estimated net output of 800 to 900 MW, for a total net plant output of approximately 1,500 MW. Such an increase in net plant output would likely require major upgrades to the three 138 kV transmission lines tied to Meramec. For the purposes of this study, only the conversion of the Unit 4 STG (Option A09) in a combined cycle was evaluated. If the preliminary characteristics for the Unit 4 STG conversion in a combined cycle option seem promising, then further study could be performed to evaluate the potential for conversion of the Unit 3 STG or Unit 3 and 4 STGs in combined cycles.

Meramec Repowering – Unit 3 & Unit 4 STGs in a Shared CCCT Conversion (Option A11)

This option is not feasible for the same reasons that Option A10 is not feasible.

Greenfield – Natural Gas-Fueled Rankine Cycle (Option A14)

This technology is considered obsolete. Past generation planning efforts have shown this option to be noncompetitive compared with other technologies. Black & Veatch is not aware of any new projects that were developed with this technology in the recent past.

Meramec Repowering – Unit 3 Boiler Replacement and STG Rebuild (Option B02.1)

This option is not feasible because of the scope of additional pollution control equipment anticipated to be needed to meet air emission limitations for particulate matter (PM), sulfur dioxide (SO_2) and nitrogen oxide (NO_x). The following scope of work applies to the Meramec Unit 3 and 4 options in which the boilers would be replaced and the STG sets would be refurbished:

1. Boiler - New waterwalls.
2. Boiler - Major superheater and reheater retrofits.
3. Steam piping modifications (main steam, cold reheat, and hot reheat).
4. Feedwater system modifications.
5. Hot well pump overhaul.
6. DA replacement (excluding DA storage tank).
7. One feedwater heater replacement.
8. Condenser retubing.
9. Induced draft fan motor and rotor modifications.
10. Water cannon replacement.
11. Unit-specific bottom ash system.
12. Fly ash collection system.
13. Significant structural steel modifications.
14. Demolition.
15. STG intermediate pressure (IP) retrofit.
16. STG high pressure (HP) stator rewind and rotor replacement.
17. STG low pressure (LP) stator rewind and rotor replacement.
18. STG static excitation retrofit.

Meramec Repowering – Unit 4 Boiler Replacement and STG Rebuild (Option B02.2)

This option is not feasible for the same reasons that Option B02.1 is not feasible. [Note: The LP and HP rotors were re-wound in 2013].

Meramec – Unit 3 & 4 Boiler Replacement with Oxyfuel Coal Boilers (Option B04)

This option is not feasible because of the scope of additional pollutions control equipment anticipated to be needed to meet air emission limitations for PM, SO_2 and NO_x. In addition, if traditional cryogenic air separation units (ASUs) are used, it is likely that space requirements will likely require modification and relocation of existing equipment. Space available around the Unit 3 and 4 boilers is inadequate for siting a cryogenic ASU. On the basis of previous Black & Veatch estimates, the increased auxiliary loading due to the ASUs would reduce the net plant output by approximately 25 percent and would reduce plant efficiency in excess of 10 percentage points. Taking a longer-term outlook, if Ion Transport Membranes (ITMs) become commercially available for air separation, the space requirements would be reduced, and depending on the configuration, plant output could actually increase by about 20%. However, cost would still be very high. Levelized cost of electricity for a greenfield oxy-combustion plant using ITM technology is upwards of $140/MWh (in 2009 dollars) based on an

Electric Power Research Institute (EPRI) report entitled *Plant-Wide Performance and Cost Analysis of Ion Transport Membrane Based Oxy-Combustion Power Generation Systems*, Product #1022301). Retrofit costs are unknown and would require considerable front-end engineering to determine.

Meramec – Unit 3 & 4 Boiler Replacement with CFB Boilers (Option B06)

This option is not feasible because of the scope of additional pollutions control equipment anticipated to be needed to meet air emission limitations for PM, SO_2 and NO_x. Replacing existing pulverized coal (PC) boilers with new circulating fluidized bed (CFB) boiler would require extensive demolition and modification to the existing units and would most likely result in a reduction in net capacity. A brief summary of issues is listed below:

• CFB boilers have a lower thermal efficiency than PC boilers. Based on previous Black & Veatch estimates, plant efficiency with CFB boilers is typically between 1.0 and 1.5 percentage points lower than that of PC fired facilities.

• A CFB boiler is larger than the existing PC boiler. The cost to modify the existing structure to accommodate CFB boilers would be prohibitive.

• Existing coal preparation equipment would have to be replaced and/or modified.

• New limestone handling and preparation equipment would be required, which would be expensive to site.

Greenfield – Pressurized Circulating Fluidized Bed (Option B13)

At its current developmental status, this technology is not competitive compared with other technologies presented in this effort. No significant development advances have been substantiated in recent years. Limited success with pressurized fluidized bed combustion (PFBC) technology was realized with American Electric Power's Tidd Unit 1, which concluded operations in 1991. More recent pressurized fluidized bed (PFB) projects are currently in operation in Japan, such as Chugoku Electric Power Company's Ohsaki plant, Kyushu Electric Power's Karita plant, and Hokkaido Electric Power Company's Tomatouatsuma plant. Other commercial plants in operation in Europe include Fortum's Vartan plant and E.ON's Escatron plant. A number of operational and performance issues have been experienced with the greatest frequency of incidences occurring in the hot gas cleanup from the PFB to the gas turbine and gas turbine blade deposition, erosion and corrosion due to particulate carry-over in the hot gas path. Due to a relative lack of performance and cost sharing, Black & Veatch is unable to comment on the performance and cost of these projects.

In the United States, recent efforts exploring Advanced PFBC, where the gas turbine is driven partially by hot gases from a pressurized circulating fluidized bed and partially from a topping combustor that receives syngas from a fluidized bed carbonizer (often referred to as a gasifier), have resulted in little progress. In 1990, pilot scale component testing of Advanced PFBC components and systems integration began at the Wilsonville Power Systems Design Facility (PSDF). In 2000, after 170 hours of operation on coal, Foster Wheeler, the major equipment supplier, pulled out of the project and further testing was cancelled. No significant efforts have succeeded this work.

Greenfield – Pressurized Bubbling Fluidized Bed (Option B14)

Similar to Option B13, Option B14 has not been proven competitive.

Compliance References