

Methodology for Fleetwide Energy Efficiency Analysis

1021206

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Technical Update, December 2010

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ACKNOWLEDGMENTS

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The PEET was comprised of subject matter experts from Ameren Missouri, Ameren Services, and EPRI. Special thanks to Corporate Planning, Environmental Services Department, Power Operations Services, Finance & Corporate Services, and EPRI for supporting the team's efforts.

This publication is a corporate document that should be cited in the literature in the following manner:

Methodology for Fleetwide Energy Efficiency Analysis. EPRI, Palo Alto, CA: 2010. 1021206.

ABSTRACT

Making power plant efficiency improvements is a proven and low-cost method for CO₂ reductions in the near term. In this report, a methodology EPRI previously developed for evaluating efficiency improving projects in a single power plant was applied to all twelve coal-fired plants in the Ameren Missouri fleet. A list of feasible energy efficiency options was compiled and analyses were conducted to determine project-specific net annual benefits in relation to reduction of CO₂ emissions. Researchers compiled information from various internal sources and then added more projects from the EPRI capital projects report. All projects were listed in a spreadsheet and normalized to match each unit within the Ameren Missouri system.

The list of projects in this report is not an exhaustive list and can be updated as new ideas and technologies become available. The main outputs of the report in relation to CO₂ reductions are organized in a spreadsheet format and displayed in a bar chart for an overall view of the projects. Each project has specific data and information compiled in a common format. This common format page gives a project description and expected benefits. Since there is uncertainty in the dollar estimates, high, expected, and low estimates are provided. The outputs of the report show each project for each unit for Ameren Missouri. The data collected in the report is based on estimated heat rate reduction, auxiliary load reduction, capacity increase, equivalent forced outage rate (EFOR) reduction, and emissions benefit. The plant MW output has been held constant so the benefits could be shown in terms of CO₂ reductions.

While many of these estimates are based on generic EPRI analysis and need to be evaluated in more detail to determine the full applicability and benefit of the projects on a unit-by-unit basis, many potential projects to improve plant energy efficiency and reduce CO₂ emissions were identified. Initial evaluation indicates there may be some projects that should be investigated further regardless of the value of CO₂. These projects are estimated to reduce CO₂ emission by about 1 million tons per year. If CO₂ credits are worth \$26/ton, there are additional projects that are worth further consideration. These additional projects are estimated to reduce CO₂ emission by an additional 200,000 tons a year. The upper limit for Ameren Missouri coal plant CO₂ reductions through the efficiency improvements considered was estimated to be about 2 million tons a year (about 5% of emissions).

Keywords

Greenhouse gases

CO₂

Energy efficiency

Coal-fired power plants

Heat Rate

EXECUTIVE SUMMARY

Report Description

This report was developed to show how coal plant energy efficiency improvements could be used to reduce carbon dioxide (CO₂) emissions. The Plant Energy Efficiency Team (PEET) was established in April 2009 to explore Ameren's options for improving coal plant efficiency. The PEET results are focused on tons of CO₂ avoided or reduced and the cost per ton of CO₂ avoided or reduced (\$/ton). The estimated cost per ton of CO₂ avoided or reduced for each technology can be used to determine which projects are potentially viable based on the price of CO₂ credits.

Background

This report is considered a high-level screening tool that can be used to pick promising projects for further study. Some of the projects were based on current studies within the Ameren Corporation and others were based on Electric Power Research Institute (EPRI) analysis of a generic 500-MW plant. The EPRI data was normalized to reflect the size of each unit within the Ameren system.

PEET Objectives

The PEET objectives are listed below:

- Develop a list of potential energy efficiency options
- Screen list for unit feasibility
- Prepare associated capital and operations and maintenance (O&M) estimates for feasible options
- Conduct analyses to determine project-specific net annual benefit in relation to the reduction of CO₂ emissions
- Prepare a final report identifying the CO₂ reduction options at each plant

Approach

PEET compiled information from various internal sources and then added more projects from the EPRI capital projects report. All projects were listed in a spreadsheet and normalized to match each unit within the Ameren Missouri system. This report covers only projects for existing coal-fired power plants. This was not an Integrated Resource Plan (IRP) study; the PEET was not trying to determine how best to increase generation. The assumption was made that net plant

output remains constant. If the proposed project happened to increase capacity along with efficiency, the fuel burn was reduced to hold net output constant. CO₂ emissions reduced or avoided were then calculated and summarized.

Results

The list of projects in this report is not an exhaustive list and can be updated as new ideas and technologies become available. The timeframe for developing this report did not allow an exhaustive search for all potential projects. The main outputs of the report in relation to CO₂ reductions are organized in a spreadsheet format and displayed in a bar chart for an overall view of the projects. Each project has specific data and information compiled in a common format. This common format page gives a project description and expected benefits. Since there is uncertainty in the dollar estimates, high, expected, and low estimates are provided.

The outputs of the report show each project for each unit for Ameren Missouri. The data collected in the report is based on estimated heat rate reduction, auxiliary load reduction, capacity increase, equivalent forced outage rate (EFOR) reduction, and emissions benefit. The plant MW output is held constant so the benefits could be shown in terms of CO₂ reductions. Not all projects show a benefit and some are not economically viable. It should be noted that most of the cost and benefit estimates were made using EPRI generic plant data scaled to represent the Ameren Missouri units.

Analysis Summary

- There are many potential projects to improve plant energy efficiency and reduce CO₂ emissions.
- The PEET assessment indicated:
 - Initial evaluation indicates there may be some projects that should be investigated further regardless of the value of CO₂. These projects are estimated to reduce CO₂ emission by about 1 million tons per year.
 - If CO₂ credits are worth \$26/ton, there are additional projects that are worth further consideration. These additional projects are estimated to reduce CO₂ emission by an additional 200,000 tons a year.
 - The upper limit for Ameren Missouri coal plant CO₂ reductions through the efficiency improvements considered was estimated to be about 2 million tons a year (about 5% of emissions).
- The project cost and performance information available to the team was generally high-level, which impacted the quality of the cost and CO₂ benefit estimates. Additional analysis is required to determine the benefits and applicability before any of these projects are implemented.

The following top projects may be justified without any CO₂ credits and should be given further consideration:

Top Projects
[Based on Net Annual Cost per ton of CO₂ Avoided (\$/ton of CO₂)]
• Automate Boiler Drains (12 units)
• Air Heater Seals (8 units)
• Station Air System (2 units)
• Circulating Water Strainers (8 units)
• Air Heater Baskets (4 units)
• Condenser Ball Cleaning System (8 units)

Many of these estimates are based on generic EPRI analysis and need to be evaluated in more detail to determine the full applicability and benefit of the projects on a unit by unit basis. The above list provides some of the project types that appear to have the most benefit and should be given further consideration and analysis.

Recommendations

The Ameren Missouri PEET has the following recommendations for future activities:

- Conduct in-depth engineering studies of top options.
- Monitor EPRI work on efficiency and heat rate. Monitor potential operations and maintenance efficiency measures. (See *Capital and Maintenance Projects for Efficiency Improvements* - EPRI Report 1019002, 2009).
- Update PEET screening analysis periodically.

CONTENTS

1 INTRODUCTION	1-1
Methodology for Ranking Efficiency Improvements for CO ₂ Reduction in Coal-Fired Power Plants—EPRI Introduction	1-1
2 BACKGROUND.....	2-1
2.1 Purpose.....	2-1
2.2 Objectives	2-1
2.3 Project Scope.....	2-2
3 METHODOLOGY	3-1
3.1 Task 1: Project Identification	3-1
3.2 Task 2: Technology Feasibility Screening.....	3-2
3.3 Task 3: Fatal Flaw Analysis to Eliminate Options	3-3
3.4 Task 4: Data Collection and Input Identification	3-5
3.5 Task 5: Analysis and Ranking of Projects for CO ₂ Reductions and Efficiency Improvements	3-5
3.6 Task 6: Reasonability Check of Results.....	3-5
4 ANALYSIS.....	4-1
4.1 Data Parameters	4-1
4.2 Calculations.....	4-3
4.2.1 Net Annual Benefit Calculations	4-3
Estimated Capital Cost (\$000).....	4-3
Additional O&M Cost (\$000)	4-4
Heat Rate Reduction (%).....	4-4
Heat Rate Reduction (Btu/Kwh).....	4-4
Estimated Auxiliary Power Load Benefit (MW)	4-4
Capacity Increase (%)	4-4
Equivalent Forced Outage Rate (EFOR) Improvement (\$000/yr).....	4-4

Heat Rate Benefit (\$000/Yr).....	4-5
Emissions Benefits (\$000)	4-6
Net Annual Benefit (\$000/yr).....	4-6
4.2.2 CO ₂ Reduction Calculations	4-7
4.2.3 Net Annual Cost Calculations (\$/ton of CO ₂ avoided or reduced)	4-7
4.3 Limitations	4-8
5 RESULTS	5-1
5.1 Ameren Missouri PEET Analysis.....	5-1
5.1.1 Ameren Missouri PEET Sensitivity Analysis.....	5-5
5.2 Corporate Project Evaluation	5-6
5.3 Key Observations.....	5-6
6 FUTURE ACTIVITIES.....	6-1
7 REFERENCES	7-1
A AMEREN MISSOURI HEAT RATE IMPROVEMENT PROJECT OPPORTUNITY FORMS	A-1
B AMEREN MISSOURI PEET ANALYSIS—PROJECT RANKING LIST	B-1
C AMEREN MISSOURI PEET SENSITIVITY ANALYSIS—VARIOUS ECONOMIC LIFE SCENARIOS.....	C-1

LIST OF FIGURES

Figure 5-1 Cumulative CO ₂ Reduction and Cost per Ton of CO ₂ Reduced	5-3
Figure 5-2 Cumulative CO ₂ Reduction and Cost per Ton of CO ₂ Reduced	5-4
Figure 5-3 Ameren Missouri PEET Summary - CO ₂ Emission Breakdown according to Net Annual Cost (\$/ton of CO ₂)	5-7

LIST OF TABLES

Table 3-1 PEET Master List of Generation Efficiency Projects by Major Plant Systems	3-2
Table 3-2 Ameren Missouri PEET Project Feasibility Matrix	3-4
Table 4-1 Ameren Missouri Unit Performance Assumptions	4-1
Table 5-1 Ameren Missouri PEET Analysis Summary	5-5
Table 5-2 Ameren Missouri PEET Sensitivity Analysis Summary	5-5

1

INTRODUCTION

This report summarizes the results of Plant Energy Efficiency Team (PEET) efforts. The PEET was established in April 2009 to explore Ameren’s options for improving coal plant efficiency. The PEET focused on potential generation projects that will reduce carbon dioxide (CO₂) emissions at the Ameren Missouri coal-fired power plants.

Methodology for Ranking Efficiency Improvements for CO₂ Reduction in Coal-Fired Power Plants—EPRI Introduction

Making power plant efficiency improvements is a proven and low-cost method for CO₂ reductions in the near term. The EPRI report *Capital and Maintenance Projects for Efficiency Improvements* (1019002) published in 2009 provides a standardized methodology for evaluating specific projects for individual units. In the report, the method was applied to a typical 500-MW generating unit, and values were estimated for costs and benefits in order to establish a “net worth” for each project explored. That net worth included not only CO₂ emissions reductions, but also fuel savings, potential increased generating capacity, and nitrogen oxides (NO_x) and sulfur dioxide (SO₂) emissions reductions.

The most powerful use of this approach is to apply the method to an entire fleet, where a set of potential projects can be evaluated for a group of specific coal-fired units. In the end, the projects can be ranked in terms of dollars per ton of CO₂ removed. Working with EPRI Heat Rate and Cost Optimization project managers, Ameren has demonstrated how this task can be completed and the usefulness of the results.

The steps used to apply this evaluation fleet-wide include the following:

- Assemble a team of experts within the utility with collective knowledge covering all of the units being investigated and all the projects being considered.
- Identify the potential projects, using the spreadsheet in EPRI Report 1019002 as the starting point.
- Identify the coal-fired units to be included in the analysis.
- Screen projects for feasibility of application to each unit in the fleet.
- Determine project attributes for each application.
- Evaluate the applicable projects for each unit.
- Develop project ranking based on the cost-benefit analysis for each application.

- Prepare Pareto curves to provide management with a decision-making tool to prepare for any future carbon-related charges.
- Issue fleet-specific report.

The first bullet is crucial to the completion of a successful project. The assembled team must have the knowledge to identify which projects are feasible for each unit and to provide reasonable estimates of the projects' costs, installation implications, and effects on unit performance.

Ameren engineers first customized the spreadsheet from the EPRI report to mirror their internal analytical practices. They employed their own unit-specific estimates for potential projects when available, and otherwise used default values from the EPRI report.

This report describes the technique of applying this evaluation fleet-wide, the steps involved, and the reporting options to create the most meaningful results. The derived Pareto curves allow management to apply Pareto's Principle, also known as the 80-20 rule. In the case of Ameren Missouri, they could spend approximately \$800M to implement all of the projects and remove 2,000,000 tons of CO₂ annually, as shown in Figure 5-2. However, they could remove half that much, or 1,000,000 tons of CO₂ annually, for an estimated cost of approximately \$70M. The curve allows management to assess the total cost of any level of CO₂ removal and to identify the projects needed to implement that decision.

2

BACKGROUND

2.1 Purpose

Ameren's 2007 Environmental Stewardship Report identified that Ameren is committed to "play a central role in advancing efforts to reduce CO₂ levels." The PEET was established in April 2009 and the team included subject matter experts from Ameren Missouri, Ameren Services and Electric Power Research Institute (EPRI). The purpose of the PEET was to explore Ameren's options for improving coal plant efficiency and therefore reduce CO₂ emissions.

PEET was tasked with conducting a high-level screening analysis to identify potentially promising plant efficiency projects. PEET evaluated energy efficiency projects at existing coal-fired plants only, the CO₂ reductions in relation to these efficiency improvements, and order-of-magnitude costs. Other opportunities may exist beyond those projects considered here. For example, PEET did not address CO₂ capture technologies, renewable fuels, new generation facilities, detailed cost analysis of specific technologies, or maintenance activities.

2.2 Objectives

The PEET objectives are listed below:

- Develop a list of potential energy efficiency options
- Screen list for unit feasibility
- Prepare up-front cost estimates and associated O&M estimates for feasible options
- Conduct analyses to determine project-specific net annual benefit in relation to the reduction of CO₂ emissions
- Prepare final report identifying CO₂ reduction options at each plant

2.3 Project Scope

The PEET analysis addressed projects for energy efficiency improvement at existing coal-fired power plants that would result in CO₂ reductions. The PEET analysis provided a high-level screening of numerous projects for energy efficiency associated with Ameren Missouri's 12 coal-fired units. The screening was based on project information that was obtained from internal and external sources. A detailed cost analysis of specific technologies was not part of the PEET analysis.

Many other opportunities for CO₂ reductions may exist for Ameren Missouri in the generation sector. For example, CO₂ capture technologies, renewable fuels, new generation facilities with the latest technologies, and potential maintenance projects for energy efficiency were not included in the PEET analysis.

3

METHODOLOGY

This effort was initiated by establishing a six-step approach developed by EPRI that divides the assessment effort into logical steps designed to ensure a reasonably high-level comprehensive and technical analysis. The PEET analysis was based on *Capital and Maintenance Projects for Efficiency Improvements* (EPRI Report 1019002, 2009). The EPRI report identified the major systems in a typical solid-fuel generating plant and developed a list of potential projects that could improve the performance of these systems. EPRI developed an Excel spreadsheet model that calculates the benefits and costs of each of these projects for a hypothetical 500-MW coal-fired power plant.

This section describes the six-step process and the issues associated with each. Below is the process overview:

1. Project Identification
2. Technology Feasibility Screening
3. Fatal Flaw Analysis to Eliminate Options
4. Data Collection and Input Identification
5. Analysis and Ranking of Projects for CO₂ Reductions and Efficiency Improvements
6. Reasonability Check of Results

The PEET was comprised of subject matter experts from Ameren Missouri, Ameren Services, and EPRI. PEET complied with the Federal Energy Regulatory Commission (FERC) Code of Conduct requirements.

3.1 Task 1: Project Identification

The purpose of this task was to help find the options that are applicable to the Ameren Missouri coal-fired power plants. In 2007, this effort began with the identification of the major systems in a typical solid-fuel generating plant produced by Generation Technical Services. The PEET had additional brainstorming sessions and added to the list of potential options. In addition, PEET added projects contained in the EPRI Reports.

3.2 Task 2: Technology Feasibility Screening

The purpose of this task was to identify projects that could potentially result in efficiency improvements at Ameren Missouri coal-fired power plants. Ultimately, over 40 candidate project types were identified by six major plant systems. Table 3-1 presents the major plant systems and associated projects that were identified.

**Table 3-1
PEET Master List of Generation Efficiency Projects by Major Plant Systems**

Boilers (10)	Turbines & Generators (15)
Intelligent Sootblowing System (ISB) Economizer retrofit Water cannons Automate boiler drains On-site fuel drying Blowdown recovery tank Air heater seals Air heater baskets Heat rate/performance monitoring Combustion/optimization monitoring system	HP/IP/LP steam seal upgrade (3) HP/IP/LP steam path upgrade (3) HP/IP/LP turbine replacement (3) LP turbine last-stage buckets Exhaust hood steam guide modification Rewind generator Increase hydrogen purity Partial-arc admission Sliding pressure
Condensers (8)	Fans & Motors (4)
Run with one circulation pump when temperatures are favorable Condenser ball cleaning system Re-tube condensers Water box vacuum priming system Circulating water strainers Circulating water turbine Supplemental cooling towers Deep lake water intake	Fan variable frequency drive (VFD) Forced draft fan VFD Induced draft fan VFD High-efficiency motors / boiler feed pump drives
Air Quality Control System (AQCS) Precipitators (2)	Balance of Plant (2)
Variable power input Power supply upgrade	Upgrade air compressors Plant lighting upgrade

HP = High Pressure
 IP = Intermediate Pressure
 LP = Low Pressure

3.3 Task 3: Fatal Flaw Analysis to Eliminate Options

The purpose of this task was to conduct a fatal flaw analysis to determine the feasibility of the efficiency projects on a unit-by-unit basis at the Ameren Missouri coal-fired power plants, using the project list developed in Task 2. Twelve coal-fired units were considered in the fatal flaw analysis. Many potential projects may not be feasible for a particular plant or unit based on the configuration of the plant. For example, LP turbine replacement is not a potential project for a unit that just replaced its LP turbine. Numerous energy efficiency projects have already been completed.

Over 490 individual potential projects were identified and screened for feasibility. Of these, 174 projects were identified by PEET as potentially feasible projects. Table 3-2 presents the Ameren Missouri Plant Energy Efficiency Project Feasibility Matrix. Note that the twelve coal-fired units in the Ameren Missouri fleet were randomly identified as units A-L to maintain their confidentiality.

**Table 3-2
Ameren Missouri PEET Project Feasibility Matrix**

COMPONENT	Unit											
	E	F	G	H	A	B	C	D	K	L	I	J
Condensers												
Run with one circulation pump when temperatures are favorable	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Water Box Vacuum Priming System	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Circulating Water Turbine/Discharge Turbine	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Condenser Ball Cleaning System	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Circulating Water Strainers	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Condenser Retube	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Supplemental Cooling Towers	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Deep Lake Water Intake	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Boilers												
Intelligent Sootblowing System (ISB)	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Combustion/Optimization Monitoring System	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Heat Rate/Performance Monitoring	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Economizer Retrofit	Red	Red	Red	Red	Red	Green	Green	Red	Red	Red	Red	Red
Air Heater Baskets	Red	Green	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red
Air Heater Seals	Green	Red	Green	Green	Red	Red	Red	Red	Red	Green	Red	Red
Water Cannons	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Automate Boiler Drains	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
On-Site Fuel Drying	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Blowdown Recovery Tank	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Turbines/Generator												
High Pressure (HP) Turbine Replacement	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red	Red	Red
Intermediate Pressure (IP) Turbine Replacement	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red	Red
Low Pressure (LP) Turbine Replacement	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
HP Steam Seal Upgrade	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
IP Steam Seal Upgrade	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
LP Steam Seal Upgrade	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
HP Steam Path Upgrade	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
IP Steam Path Upgrade	Red	Red	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
LP Steam Path Upgrade	Red	Green	Red	Red	Red	Red	Red	Green	Red	Red	Red	Red
Exhaust Hood Steam Guide	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
LP Last Stage Buckets	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Generator Rewind	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
H ₂ Purity	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Partial Arc Admission	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Sliding Pressure	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Precipitators												
ESP Variable Power	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
ESP Power Supplies	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Fans / Motors												
High Efficiency Motors	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
FD Fan VFD	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
ID Fan VFD	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
PA Fan VFD	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red
Balance of Plant												
Plant Lighting Upgrade	Green	Green	Green	Green	Red	Red	Red	Red	Red	Red	Red	Red
Station Air System	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red	Red

STATUS shown by color	Red	Not applicable or project completed
	Green	Potentially feasible

3.4 Task 4: Data Collection and Input Identification

The purpose of this task was to compile data and inputs for the analysis. A significant number of assumptions were necessary in order to effectively characterize the options and economics for each unit. PEET contacted several internal Ameren Missouri sources, as well as EPRI, in order to obtain the input parameters.

The following input parameters were compiled:

- Annualized Up-front Cost (\$/yr)
- Heat Rate Reduction (%)
- Auxiliary Load Benefit (MW)
- Availability Increase (%)
- Unit Capacity (MW)
- Heat Input (mmBtu/yr)
- NO_x, SO₂, CO₂ Emissions (lb/mmBtu)
- Levelized Fixed Charge Rate (% , 30-YR Economic Life)
- Incremental O&M Cost (\$/yr)
- Unit Heat Rate (Btu/kWh)
- Capacity Increase (%)
- Reliability Increase (%)
- Replacement Power Cost (\$/MWh)
- Fuel Cost (\$/mmBtu)
- NO_x, SO₂, CO₂ Emissions Credit Price (\$/ton)

3.5 Task 5: Analysis and Ranking of Projects for CO₂ Reductions and Efficiency Improvements

The purpose of this task was to conduct analysis and rank projects for CO₂ reductions and efficiency improvements relative to each other.

The analysis is discussed in more detail in Section 4.0. The results are discussed in more detail in Section 5.0.

3.6 Task 6: Reasonability Check of Results

The purpose of this task was to evaluate a few projects using the Ameren Missouri corporate assessment tool to confirm the analysis results over a 30-year study period. The evaluation is discussed in more detail in Section 5.0.

4

ANALYSIS

Efficiency improvements in the generation sector can increase capacity, lower auxiliary power demands, and increase availability and reliability. The PEET analysis was based on the EPRI methodology used to assess the costs and potential benefits of improvements to coal-fired power plants. The potential benefits were calculated for a hypothetical 500-MW plant, including the heat rate reductions benefit, reduction in auxiliary load, capacity increase, and equivalent forced outage rate (EFOR) improvement. In addition, some generation project improvements would have the effect of reducing CO₂ emissions for the same level of electricity output. The PEET analysis did consider the monetary impact of avoided CO₂ emissions, based on an assumed market price of CO₂ that might arise from pending federal legislation.

This section describes the data assumptions and inputs, the calculations, and the limitations of the PEET analysis.

4.1 Data Parameters

In order to conduct the PEET analysis, several input parameters were required as listed in Section 3.4 above.

Also, as previously mentioned, a generic 500-MW (net) unit was the reference case for the development of the EPRI methodology. The EPRI reference assumptions are included in Table 4-1. The Ameren Missouri unit-specific information has been deleted from the report to maintain confidentiality.

**Table 4-1
Ameren Missouri Unit Performance Assumptions**

	1	2	3	4	5	6	7	8
Unit	Unit Number	Capacity (Net MW)	Capacity Factor (%)	Net Unit Heat Rate (Btu/kWhr)	Heat Input (mmBtu/year)	Replacement Power Cost (\$/MWh)	Fuel Cost (\$/mmBtu)	Fixed Charge Rate (%)
EPRI Reference	1	500	80	10000	35,040,000.00	37.71	1.25	12.00%
A	2							
B	3							
C	4							
D	5							
E	6							
F	7							
G	8							
H	9							
I	10							
J	11							
K	12							
L	13							

Table 4-1 (continued)
Ameren Missouri Unit Performance Assumptions

	9	10	11	12	13	14	15	16
	CO2	SO2	NOx	Hg	SO2 Cost	NOx Cost	Hg Cost	CO2 Cost
Unit	(lb/mmBtu)	(lb/mmBtu)	(lb/mmBtu)	(lb/Tbtu)	(\$/ton)	(\$/ton)	(\$/lb)	(\$/ton)
EPRI Reference	251.6	0.077	0.4	0.725	\$1,200	\$1,000	\$0	\$0
A					\$242	\$0	\$0	\$26
B					\$242	\$0	\$0	\$26
C					\$242	\$0	\$0	\$26
D					\$242	\$0	\$0	\$26
E					\$242	\$0	\$0	\$26
F					\$242	\$0	\$0	\$26
G					\$242	\$0	\$0	\$26
H					\$242	\$0	\$0	\$26
I					\$242	\$0	\$0	\$26
J					\$242	\$0	\$0	\$26
K					\$242	\$0	\$0	\$26
L					\$242	\$0	\$0	\$26

The “Heat Rate Improvement Project Opportunity Forms” are another critical part of the analysis. These standard forms contain detailed descriptions of each project. This template provides essential inputs that are used in the PEET analysis. The worksheet includes an estimate of benefits (cost reduction estimates, heat rate, and auxiliary power reductions) and costs (up-front cost, additional operating costs, and maintenance). Appendix A contains the Heat Rate Improvement Project Opportunity Forms. Note that the PEET used the high estimate for costs and the average estimate for benefits. The high cost estimate was used for all projects based on comparison of the EPRI values and Ameren Missouri specific values.

Capacity improvements are the increased MW production that is gained from the installation of new equipment. These values are a direct input based on subject matter experts, Original Equipment Manufacturer’s (OEM’s) equipment case studies, or calculation from the models that were used to characterize the potential project.

Heat rate improvements are estimates of the decrease in the amount of fuel, measured in mmBtu, necessary for a typical system to achieve the same MW production. These values were obtained from a variety of different sources depending on the specific project. In some cases analyses were performed on actual plants; in other cases models were run to estimate the effect; and in certain instances the estimates were based on OEM estimates from industry proposals.

Auxiliary power reduction is based on the expected reduction in parasitic power reduction. The effect of these reductions can be estimated by two different methods based on improvement in heat rate or the increase in available power. The estimates attempt to distinguish between these two effects and avoid double counting the same effect.

Up-front costs are the costs necessary to design, procure, and install or replace a piece of equipment or system. The PEET analysis included the EPRI cost estimates as well as unit-specific data. The EPRI costs are based on OEM estimates or architectural and engineering

(A&E) estimated costs for similar projects. These estimates should be considered indicative of the possible range of prices that may be incurred at a specific site. Actual costs also vary significantly depending on a number of other issues including, but not limited to, the following:

- Specific material used
- Delivery times and/or schedule requirement
- Size of the project
- Location
- Need for site demolition
- Asbestos abatement
- Local labor prices and productivity
- New Source Review (NSR)

4.2 Calculations

An Excel spreadsheet was used to apply the EPRI methodology to the Ameren Missouri coal-fired units using plant-specific information for the analysis. Using a spreadsheet ensured consistency in evaluations and the use of the basic inputs. The spreadsheet analysis was used to determine the net annual benefit, potential reduction in CO₂ emissions, and net annual cost.

4.2.1 Net Annual Benefit Calculations

The net annual benefit calculations estimate an annual equivalent cost and compare that cost to the annual benefits expected. In cases where this value is negative, it would appear that the annual savings do not generate sufficient benefits to pay for the annualized up-front costs.

The calculations that follow use the input data specific to that project. Each of the calculated steps and its related values will be described here so that the assumptions utilized in the development of the project spreadsheet can be understood. These assumptions are used throughout the following example and the spreadsheet calculations. A description of all the remaining columns follows.

Estimated Capital Cost (\$000)

This value reflects the up-front cost required to install new equipment and/or replace existing equipment. The term “capital” is used loosely in this data label to refer to any up-front cost, whether the project actually acquires or replaces a unit of property. In each case, the “capital” cost is cross-referenced to the specific project opportunity from where it is described in more detail. The units for this column are thousands of dollars. The majority of the analysis was based on EPRI capital cost estimates that were scaled to the Ameren Missouri unit sizes. Actual cost estimates were used when possible.

Additional O&M Cost (\$000)

This value reflects the incremental or additional maintenance or operational costs that are incurred annually as a direct result of installing new equipment and/or replacing existing equipment. This value is also cross-referenced to the specific project opportunity form. The units for this column are thousands of dollars. The majority of the analysis was based on EPRI capital cost estimates that were scaled to the Ameren Missouri unit sizes.

Heat Rate Reduction (%)

In cases in which the project is expected to result in an improvement in plant efficiency via a reduction in heat rate, this column shows the expected average annual improvement expressed as a percent improvement. This information was obtained from the specific “Heat Rate Improvement Project Opportunity Forms.”

Heat Rate Reduction (Btu/Kwh)

The heat rate improvement is expressed in Btu/Kwh to make it possible to use this value in later calculations.

Heat Rate Reduction (Btu/Kwh) = Heat Rate (Btu/kWh) x % Heat Rate Reduction

Estimated Auxiliary Power Load Benefit (MW)

The value for this column is linked to the estimate in the specific “Heat Rate Improvement Project Opportunity Forms” and expressed in MW. The value represents a change in internal/parasitic station power consumption as a direct result of installing new equipment and/or replacing existing equipment. The incremental power would be available for sale on the grid.

Capacity Increase (%)

The expected increase in unit capacity is expressed as a percent of the new capability of the unit. This information was obtained from the specific “Heat Rate Improvement Project Opportunity Forms.”

Equivalent Forced Outage Rate (EFOR) Improvement (\$000/yr)

The EFOR improvement is the projected project’s effect on unit reliability and availability as combined into a single value and expressed in thousands of dollars per year. Embedded in this calculation is a reference to cells in the project worksheet that estimate the improvement in both availability and reliability. Each of these values is expressed as the improvement EFOR from each issue. Thus, a value of 1% reliability would be a 1% improvement in unit EFOR as a result of a reduction in forced outages.

EFOR Improvement

$$= \frac{(\text{availability} + \text{reliability}) \times (\text{capacity} \times 8,760 \times \text{capacity factor} \times \text{replacement power cost})}{1000}$$

For example, a 1% improvement in reliability would result in approximately \$1.3 million dollars improvement using the generic plant data assumptions.

$$\begin{aligned} \text{EFOR Improvement} &= (0.01 \times 500 \text{ MW} \times 8,760 \text{ h/yr} \times 0.80 \times \$37.71/\text{MWh}/1000 \\ &= 1,300 \text{ thousand } \$/\text{yr} \end{aligned}$$

NOTE: For the purpose of this project, the terms availability and reliability are used in a manner that is NOT completely consistent with the standard (NERC) definitions. The procedure was followed in order to reduce the potential for double counting the same effect. For this project:

- *Availability* refers to the generating unit not being out of service for a planned or maintenance outage.
- *Reliability* refers to the unit not being in a forced outage or forced derating state.

Heat Rate Benefit (\$000/Yr)

Heat rate improvements at the twelve coal-fired units considered in the PEET scope would reduce the quantity of coal required to produce the same electricity output at the busbar. For this study, these improvements were treated as an annual stream of benefits monetized as cost savings through a reduction in fuel demands. The heat rate benefit is expressed in thousand of dollars per year. The sequence of calculations is as follows (using the generic plant data assumptions):

$$\begin{aligned} \text{Annual heat input} &= \text{capacity} \times 1000 \times \text{capacity factor} \times 8,760 \times \text{heat rate}/1,000,000 \\ &= \frac{500 \text{ MW} \times 1000 \text{ kW/MW} \times 0.80 \times 8,760 \text{ h/yr} \times 10,000 \text{ Btu/kWh}}{1,000,000} \\ &= 35,000,000 \text{ mmBtu/yr} \end{aligned}$$

This value is used to estimate the fuel savings per year.

$$\text{Total annual fuel reduction} = \text{annual heat input} \times \text{heat rate reduction } \%$$

The annual heat rate benefit expressed in \$000/yr is calculated from the heat reduction and the fuel cost.

$$\text{Heat rate benefit } \$000 = \text{heat reduction (mmBtu/yr)} \times \text{fuel cost } (\$/\text{mmBtu}) / 1000$$

Emissions Benefits (\$000)

Emission benefits focus on cost savings that result from reductions in emissions of SO₂, CO₂ and NO_x. NO_x reduction benefits are calculated as follows:

NO_x reductions (tons/yr) = NO_x emissions (lb/mmbtu) x heat reduction (mmbtu/yr) / (2000 lb/ton)

NO_x reduction value (\$/yr) = NO_x reduction (tons/yr) x emissions cost (\$/ton)

SO₂ and CO₂ emission reduction values are calculated in the same manner. The PEET analysis did consider the monetary impact of avoided CO₂ emissions, based on an assumed market price of CO₂ that might arise from pending federal legislation.

Though no mercury (Hg) emissions market values are currently incorporated in the spreadsheet, the value of reductions in Hg would be calculated in a similar manner, except that the units of Hg emissions would be expressed in pounds per year instead of tons per year, due to the very small amounts of Hg that may potentially be emitted.

The total emission benefits are expressed in thousand of dollars per year. Total emissions benefits are calculated as follows:

Emission benefit with CO₂ (\$000/Yr) = NO_x value + SO₂ value + CO₂ value

Emission benefit without CO₂ (\$000/Yr) = NO_x value + SO₂ value

Net Annual Benefit (\$000/yr)

The net annual benefit provides a final valuation for each of the projects considered in the spreadsheet. The annual benefit is simply the net difference between the benefits (reduced fuel costs, improved sales, and reduced emissions) and the costs (up-front costs and operating expenses). The basic idea is that if the project generates more savings on an annual basis than what is necessary to pay the capital charge and cover any additional O&M expenses required by the improvement, there is benefit to the company. The annual charge is estimated by taking the up-front cost times a fixed charge rate (FCR) that reflects the company's cost of capital. Again, no evaluation was made whether the up-front costs actually meet the accounting definition of "capital".

To restate these relationships:

Benefits:

heat rate + emissions + added power sales = total benefits

Costs:

additional O&M expenses + capital cost x FCR = total costs

Net annual benefit = benefits – costs

The above sections detail the calculations using the EPRI methodology for the determination of net annual benefit. As such, the benefit of added power sales and reduced CO₂ emissions were considered in the calculations. Ameren Missouri's desire was to evaluate projects under the assumption that the capacity of the units would be held constant. In addition, the benefit of CO₂ emission reductions was omitted from the calculations so that the cost of each project in terms of \$ per ton of CO₂ removed cost could be compared to the value of CO₂ emissions. The details of the Ameren Missouri specific calculations are given in Sections 4.2.2 and 4.2.3.

4.2.2 CO₂ Reduction Calculations

The CO₂ reduction calculations estimate the potential amount of CO₂ emissions that would be avoided if the unit-specific project were implemented. For the CO₂ emission reduction estimates, the PEET assumed that the net output generation of the unit would remain constant. In addition, the PEET assumed that the capacity increases would be converted into an equivalent heat rate improvement. Total CO₂ emissions reductions are calculated as follows:

CO₂ tons avoided (heat rate improvement)

Heat rate change (%) x annual heat input (mmbtu) x CO₂ emission rate (lb/mmbtu) / 2000 lb/ton

CO₂ tons avoided (capacity increase)

{Capacity increase (%) + auxiliary load reduction (MW)/ unit capacity (MW) – heat rate change (%)} x annual heat input (mmbtu) x CO₂ emission rate (lb/mmbtu) / 2000 lb/ton

The above equation represents the effective heat rate improvement for capacity increases that are above and beyond the heat rate improvement already included in the project estimate. Summing the above two results provides an estimate of the total potential savings in tons of CO₂.

Total CO₂ avoided = CO₂ tons avoided (heat rate improvement) + CO₂ tons avoided (capacity increase)

4.2.3 Net Annual Cost Calculations (\$/ton of CO₂ avoided or reduced)

To determine the net annual cost per ton of CO₂ avoided, the capacity increase for each project was converted to an equivalent heat rate improvement, as described in the Section 4.2.2. Again, this effective heat rate improvement due to capacity increases only considers that portion which is above and beyond the heat rate improvement values already included in each project. This additional heat rate improvement was then used to determine the additional fuel and emission benefits using the same calculations presented in previous sections. These additional benefits are then combined with the calculated costs and benefits already calculated from the heat rate improvement estimate to arrive at a net annual cost for the project (excluding potential CO₂ benefits). This number is then divided by the total tons of CO₂ avoided to determine the cost per ton of CO₂ avoided.

4.3 Limitations

The PEET spreadsheet analysis is not intended to cover every possible situation. Other factors that must be considered are the plant's design, fuel selection, and whether the age and condition of the balance-of-plant equipment can support a specific upgrade. An assessment of the plant's remaining useful life is also needed.

The costs and benefits for the majority of the projects were estimated by EPRI, based on generic power plants. The high-level estimates are based on the best available information at this time. The generic estimates were scaled to the size of the units, and unit-specific heat rates and capacity factors were used for the analysis; therefore, these estimates may not represent the actual costs for the individual units.

For the CO₂ emission reduction estimates, the PEET analysis assumed that the net output generation of the unit would remain constant. Therefore, the CO₂ emission reductions are based on reduced fuel (Btu) consumption.

Several of the unit performance assumptions are subject to change based on regulatory and market conditions (i.e. heat input, replacement power costs, fuel costs, fixed charge rate, and SO₂, NO_x, and CO₂ emission credit prices). In addition, the PEET analysis did not consider the forecast changes in emissions credits, power, or fuel costs over the life of the project.

The PEET spreadsheet analysis was intended to be a living document that should be periodically updated to ensure that the data reflects the realities of the power industry. It is likely that additional potential projects will be entered as they are identified; and the unit assumptions would be updated, as necessary.

5

RESULTS

Overall Summary:

- There are many potential projects to improve plant energy efficiency and reduce CO₂ emissions.
- The PEET assessment indicated:
 - Initial evaluation indicates there may be some projects that should be investigated further regardless of the value of CO₂. These projects are estimated to reduce CO₂ emission by about 1 million tons per year.
 - If CO₂ credits are worth \$26/ton, there are additional projects that are worth further consideration. These additional projects are estimated to reduce CO₂ emission by an additional 200,000 tons a year.
 - The upper limit for Ameren Missouri coal plant CO₂ reductions through the efficiency improvements considered was estimated to be about 2 million tons a year (about 5% of emissions).
- The project cost and performance information available to the team was generally high-level, which impacted the quality of the cost and CO₂ benefit estimates. Additional analysis is required to determine the benefits and applicability before any of these projects are implemented.

5.1 Ameren Missouri PEET Analysis

The information provided in the Ameren Missouri PEET analysis is intended for use as a high-level screening tool to compare the potential projects that may prove to be beneficial to a specific generating unit. The methodology is not intended as a rigorous project analysis. The cost, performance, and benefits of each project need to be studied in detail to improve accuracy before seeking approval for implementation.

A total of 174 projects were included in the Ameren Missouri PEET analysis. The projects were ranked according to the cost per ton of CO₂ avoided (\$/ton of CO₂) from the lowest to the highest (i.e. projects were ranked from most to least favorable). Appendix B contains the Ameren Missouri PEET Analysis – Project Ranking List. Based on the spreadsheet analysis, the project ranking will be the same regardless of a change in the CO₂ price.

Figure 5-1 is a Pareto-type supply curve that represents the cumulative CO₂ reduction and cost per ton of CO₂ reduced that is based on the Ameren Missouri PEET Analysis – Project Ranking

List. The x-axis represents the projects that were ranked in order of cost per ton of CO₂ from Project Numbers 1-174. The y-axes represent the cumulative tons of CO₂ reduced per year by all projects (green bars) and the cost per ton of CO₂ reduced by each project (blue line). The red line separates out the projects that may be justified with a net annual benefit that is ≤\$0/ton of CO₂. Projects with a negative cost per ton of CO₂ may be justified without credit for CO₂ (i.e., projects with the blue line below the red line, including project numbers 1-58). The yellow line identifies the number of projects that may be justified with a net annual benefit that is ≤\$26/ton of CO₂ (project numbers 1-90).

Figure 5-2 is a related supply curve that represents the cumulative CO₂ reduction and cumulative capital cost, based on the Ameren Missouri PEET Analysis - Project Ranking List. The x-axis represents the projects that were ranked in order of cost per ton of CO₂ from project numbers 1-174. The y-axes represent the cumulative tons of CO₂ reduced per year by all projects (green bars) and the cumulative capital cost (blue line).

Cumulative CO2 Reduction and Cost per Ton of CO2 Reduced

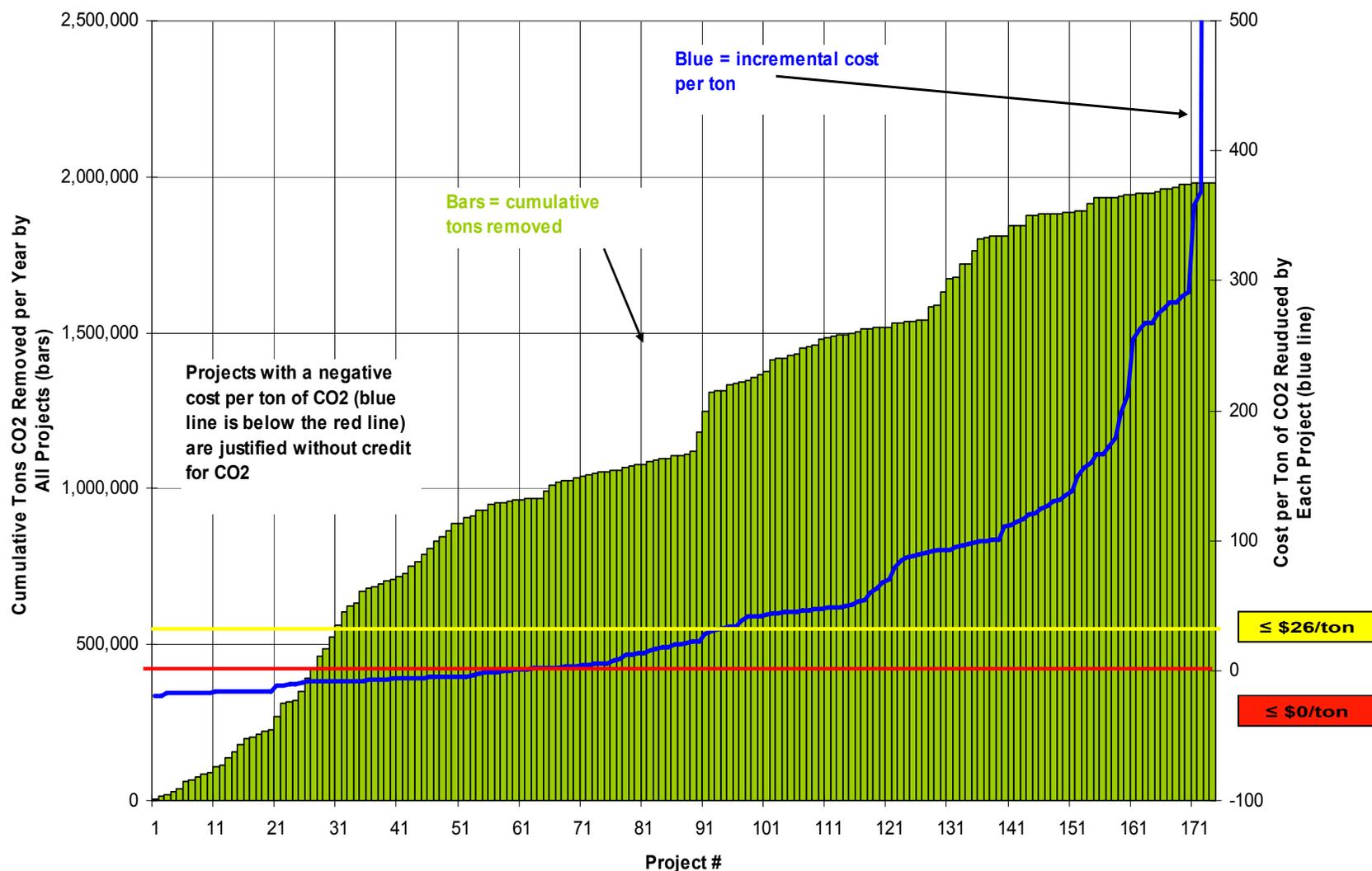


Figure 5-1
Cumulative CO₂ Reduction and Cost per Ton of CO₂ Reduced

Cumulative CO2 Reduction and Cumulative Capital Cost

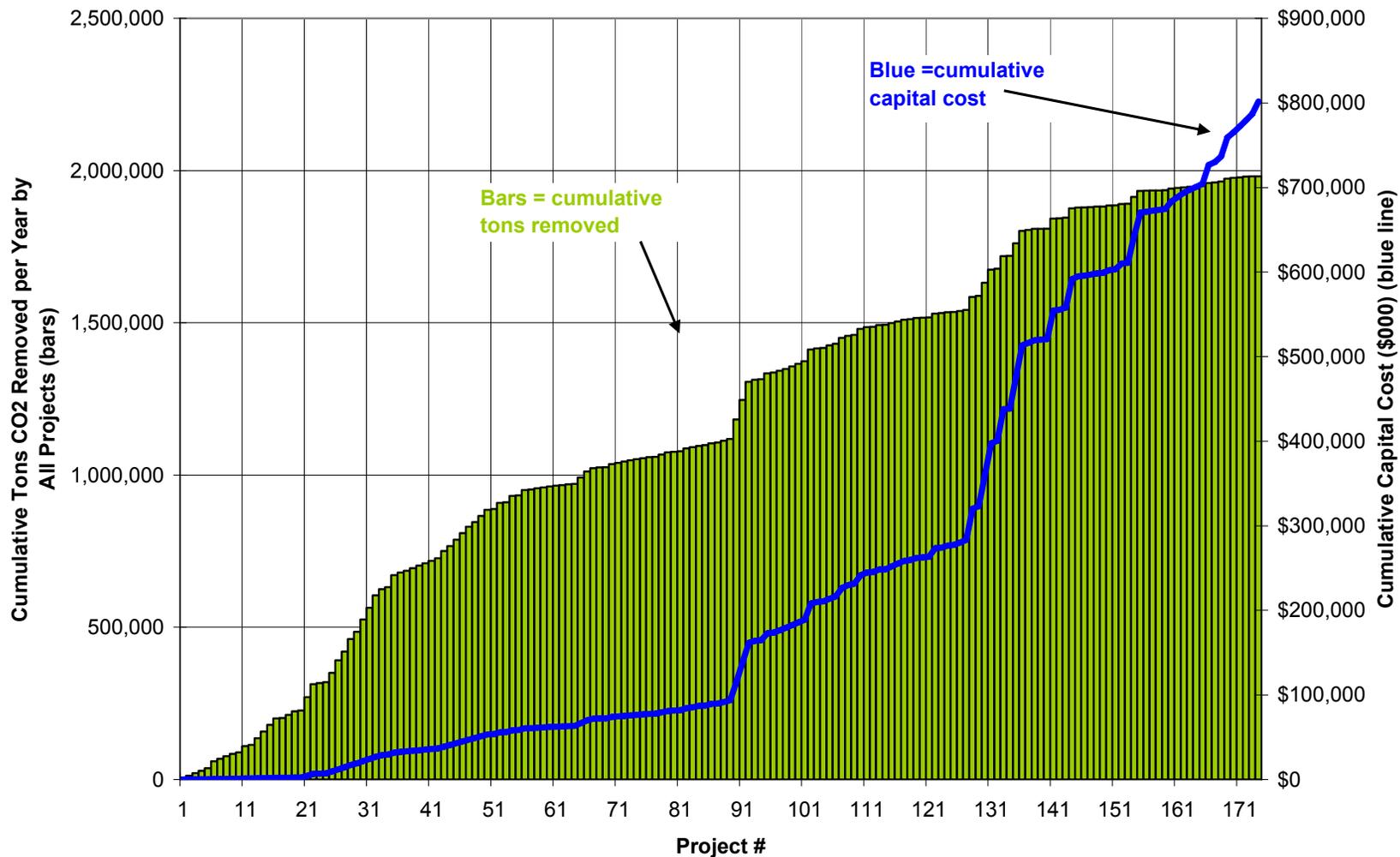


Figure 5-2
Cumulative CO₂ Reduction and Cost per Ton of CO₂ Reduced

As previously mentioned, numerous projects to improve plant energy efficiency and reduce CO₂ emissions were considered in the Ameren Missouri PEET analysis, and the projects may be justified regardless of the value of CO₂. Table 5-1 provides a summary of the Ameren Missouri PEET Analysis.

Table 5-1
Ameren Missouri PEET Analysis Summary

Net Annual Benefit (\$/ton of CO ₂)	Number of Projects	Cumulative Annual CO ₂ Emissions Avoided (tons/yr)	Cumulative Order of Magnitude Capital Cost for Projects (2009\$)
≤ 0	58	956,824	\$61,000,000
≤ 26	90	1,182,850	\$115,000,000
≤ 100	136	1,801,684	\$513,000,000
≥ 100	174	1,981,369	\$802,000,000

5.1.1 Ameren Missouri PEET Sensitivity Analysis

A sensitivity analysis was conducted assuming different periods of economic life for the Ameren Missouri PEET projects. The fixed charge rates from the Ameren Corporate EVA Model associated with 10-Year, 20-Year, and 30-Year periods of economic life were evaluated using the Ameren Missouri PEET spreadsheet. All other assumptions, as discussed in Section 4.1, remained the same.

In general, the project ranking remained in similar order for all economic life scenarios. The main difference between the various economic life scenarios was the number of projects that may be justified under \$0/ton of CO₂. Fewer projects may be justified at less than \$0/ton of CO₂ assuming a 10-year economic life compared to a 30-year economic life. Appendix C contains the Ameren Missouri PEET Analysis Sensitivity Results for the 20-year and 10-year economic life scenarios. Table 5-2 provides a summary of the Ameren Missouri PEET Sensitivity Analysis.

Table 5-2
Ameren Missouri PEET Sensitivity Analysis Summary

Economic Life	Fixed Charge Rate	Number of Projects that May Be Justified (≤ \$0/ton of CO ₂)	Cumulative Annual CO ₂ Emissions Avoided (tons/yr)	Cumulative Order of Magnitude Capital Cost for Projects (2009\$)
30-YEAR	XX.XX%	58	956,824	\$61,000,000
20-YEAR	XX.XX%	54	931,757	\$58,000,000
10-YEAR	XX.XX%	40	712,600	\$35,000,000

5.2 Corporate Project Evaluation

Ameren Missouri uses various tools for project justifications [e.g., Corporate EVA Model and ISP (project justification tool)]. Since the PEET spreadsheet analysis contained many simplified assumptions, the PEET evaluated projects using the Corporate EVA Model to confirm the spreadsheet analysis results.

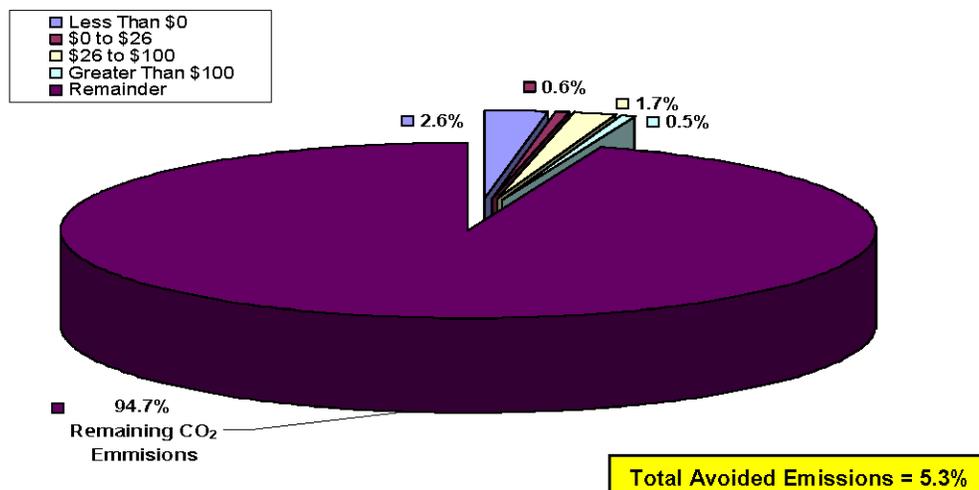
Two projects were evaluated: 1. Automate Boiler Drains – Unit J, and 2. Air Heater Baskets – Unit F. The PEET used the following assumptions for the EVA analysis:

- 30-year economic life
- Construction in the first year
- Incremental O&M and NO_x, SO₂, and CO₂ emissions costs from the PEET report
- CO₂ costs incorporated in 2014

The levelized cumulative net present value (NPV) of the annual total revenue requirement results from the Corporate EVA model were compared to the net annual cost from the Ameren Missouri PEET analysis. For the selected projects from our analysis, EVA produced similar results (i.e. if the Ameren Missouri PEET analysis indicated that the project was promising, the EVA also indicated that the project was promising).

5.3 Key Observations

There are many potential projects to improve plant energy efficiency and reduce CO₂ emissions. The Ameren Missouri PEET analysis provides a tool that will allow for numerous potential projects that improve plant energy efficiency and reduce CO₂ emissions to be evaluated and ranked easily. Based on a 30-year economic life, the Ameren Missouri PEET analysis estimated that if all 174 projects were implemented, the upper limit for Ameren Missouri coal plant CO₂ reductions through efficiency improvement would be about two million tons a year (approximately a 5.3% reduction of Ameren Missouri fleet CO₂ emissions) at an estimated capital cost of over \$800,000,000. However, initial evaluation indicates there may be some projects that should be investigated further regardless of the value of CO₂, yielding about one million tons a year in reduction of CO₂ emissions (approximately a 2.7% reduction of Ameren Missouri fleet CO₂ emissions). Figure 5-3 presents the percentage of annual CO₂ emission reductions associated with the net annual cost per project compared to the total Ameren Missouri fleet CO₂ emissions (approximately 37,000,000 tons of CO₂/year).



**Figure 5-3
Ameren Missouri PEET Summary - CO₂ Emission Breakdown according to Net Annual Cost (\$/ton of CO₂)**

The project cost and performance information available to the team was generally high-level, which impacted the quality of the cost and CO₂ benefit estimates. However, the Ameren Missouri PEET analysis can be used as a preliminary screening to identify top projects that require in-depth engineering studies. Based on the Ameren Missouri PEET analysis, several project types may be justified, no matter whether the assumed economic life is 10, 20, or 30 years. The following top projects may be justified without any CO₂ credits and should be given further consideration:

Top Projects
[Based on Net Annual Cost per ton of CO₂ Avoided (\$/ton of CO₂)]
• Automate Boiler Drains (12 units)
• Air Heater Seals (8 units)
• Station Air System (2 units)
• Circulating Water Strainers (8 units)
• Air Heater Baskets (4 units)
• Condenser Ball Cleaning System (8 units)

6

FUTURE ACTIVITIES

The Ameren Missouri PEET has the following recommendations for future activities:

- Conduct in-depth engineering studies of top options.
- Monitor EPRI work on efficiency and heat rate. Monitor potential operations and maintenance efficiency measures.
- Update PEET screening analysis periodically.

7

REFERENCES

Electric Power Research Institute (EPRI). *Capital and Maintenance Projects for Efficiency Improvements*. Report Number: 1019002. Technical Update, September 2009.

A

AMEREN MISSOURI HEAT RATE IMPROVEMENT PROJECT OPPORTUNITY FORMS

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	HP Turbine			
Project Title:	HP Steam Seal Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the HP turbine steam seals to minimize leakage losses and improve efficiency. This project will improve heat rate by minimizing steam leakage losses across the turbine blades and between the stationary nozzles and rotor. The effect on turbine performance is two-fold. With this leakage less steam is driving the rotating blades. The leaking steam, upon re-entry to the normal steam path disturbs the flow pattern adding swirl and forcing some of the steam to enter the next row of blades or stationary nozzles at non-optimal angles. By minimizing losses, more steam will be available to power the turbine, resulting in increased efficiency and capacity.			
Project Description	Leakage losses represent the greatest portion of turbine stage losses. The losses increase as the turbine packing and turbine diaphragm spill strips wear. A large amount of these losses are recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the HP turbine major inspection.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. If the turbine blade covers require redesign, the rotor will have to be sent to the supplier's shop. Turbine packing should be replaced whenever wear exceeds OEM recommendations, and accurate turbine alignment will reduce leakage losses. Packing and spill strip replacement can be performed at the plant site with the HP rotor and diaphragms removed from the unit.			
Industry Experience	There is extensive industry experience with steam seal upgrades. All major OEMs and several third party vendors offer steam seal upgrades as a standard efficiency improvement.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase HP turbine efficiency. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip losses. Discussion with the turbine engineering group indicates that even if seals were replaced, they tend to wear to the same point as the old seals. Therefore, the expected benefit will most likely be low. The EPRI minimum of 0.3% was changed to 0.1%.	0.10%	0.50%	0.80%
Aux Power Reduction	No change.	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit by a small percentage. Capacity improvements depend on the amount of deterioration the unit had suffered over its life cycle, and the previous turbine stage blade cover design. As stated above, the expected MW increase would be low due to the seals wearing after installation.	0.10%	0.40%	1.00%
Costs				
Capital Investment	Capital investment will vary based on current equipment configuration and condition. Older HP turbine designs with uncovered buckets would lead to higher capital costs. Vendor availability and the current state of the power generation repair market could also affect costs.	\$500,000	\$1,000,000	\$1,500,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	No change.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No additional outage time is expected.	0.00%	0.00%	0.00%
Reliability	No significant change in reliability is expected.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. Note that discussions with Turbine Engineering indicate that the benefit of the seal upgrades may be questionable based on their past experience.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 1 of 2)			
Major Equipment:	HP Turbine			
Project Title:	HP Steam Path Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the HP turbine to a more efficient design. This project will improve heat rate, capacity, and efficiency by adding advanced steam seals, upgraded nozzle and turbine blade profiles, upgrading materials and coatings, and (as an option) adding additional stages for greater utilization of thermal energy. An improved aerodynamic design is utilized which results in decreased profile and secondary losses.			
Project Description	Several steam path upgrades are available from OEM vendors. One upgrade involves retrofitting the current HP turbine with redesigned turbine blades and nozzles. This is known as an advanced design steam path upgrade (ADSP). The other upgrade involves providing a new HP turbine, nozzles, and HP inner shell while utilizing the current HP outer shell. If chosen, the addition of more stages will result in greater heat rate, efficiency, and reliability improvements, but at a greater cost and execution timeline. The upgrade increases the number of turbine stages while decreasing the rotor and wheel diameters. The turbine blade lengths are increased due to the decreased diameter of the rotor. All turbine blades and diaphragm nozzles are fitted with advanced design tip seals. Advanced materials, coatings, and design profiles are used to reduce the effect of solid particle erosion. The steam path upgrade requires advanced planning to allow the vendor time to implement the design and manufacture the parts. A minimum two year commitment is generally required, and the time for fabrication could increase based on the availability of materials.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. Steam path upgrades are an excellent alternative to retiring older units in favor of new generating equipment. Steam path upgrades, especially the addition of more stages, often allow power plant operators to extend the life of units beyond the 40 year design limit. Steam path upgrades are especially useful for power plant operators considering plant upgrades without re-permitting. This upgrade would eliminate the need for steam seal upgrades since these upgrades are included in the retrofit. Current (2008) lead time for a steam path upgrade can be greater than 20 months.			
Industry Experience	There is extensive industry experience with HP turbine steam path upgrades. Power plant operators enjoy the fast capital investment return and increased plant efficiency gains usually without the necessity of re-permitting. The design life of the upgrades is equal or greater than the design life of the plant. The advanced design steam path upgrades has been available from vendors since 1995.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect a significant heat rate improvement with the HP steam path upgrade. The advanced steam path with advanced sealing and advanced turbine blade and nozzle profiles greatly increases the efficiency of the HP turbine. Leakage losses, secondary losses, and profile losses, are all reduced with this upgrade. The increased efficiency leads to an increased unit capacity and decreased heat rate. If chosen, the addition of more stages will offer greater heat rate improvement than the advanced design steam path numbers listed. Specific heat rate improvements are based on the age of the unit and more detailed analysis of what design changes can be made. OEMs analysis of recent projects estimated the heat rate improvement for the HP turbine would range between 1.2 - 2.1 percent for comparable projects. The improvement is based on the original design and age of the units.	0.65%	0.83%	1.00%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit, with the amount of capacity improvement dependent on several factors. Aging units and units with increased capacity deterioration can expect greater capacity improvement. The addition of more stages offer greater capacity improvements than advanced steam path upgrades. Additionally, capacity improvement is a function of unit size. Generator, transformer, condenser and boiler maximum ratings need to be considered. Increasing the efficiency of one turbine rotor may also affect components downstream (IP,LP).	1.10%	1.50%	3.00%

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 2 of 2)			
Major Equipment:	HP Turbine			
Project Title:	HP Steam Path Upgrade			
Costs				
Capital Investment	Capital investment will depend on whether the upgrade involves just turbine blades and diaphragms or the entire rotor assembly. Rotor replacement represents approximately 80% of the upgrade cost. If chosen, the addition of more stages is more expensive as it includes replacing the HP inner shell. Rotor condition should be evaluated when selecting the type of upgrade.	\$3,000,000	\$6,000,000	\$10,000,000
Operating Costs	The HP steam path upgrade would not change operating costs for the unit. No additional operations checks or inspections will be necessary. DCS upgrades in conjunction with the HP steam path upgrade may reduce operations costs.	\$0	\$0	\$0
Maintenance Costs	The HP steam path upgrade can extend the major overhaul schedule to ten years. This decreased planned outage frequency will reduce the overall maintenance costs of the HP turbine. In a 30 year span, two major planned outages will be eliminated. The real costs savings depends on the value of extending future outages and is unit and system specific. Therefore, an estimate of the annual cost savings is not included. However, individual power plant operators can and should evaluate the benefit of the postponement of a major outage.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The HP steam path upgrade extends the major maintenance cycle from six to ten years. Advanced nozzle and turbine blade designs result in minimizing solid particle erosion are utilized. Computer modeling of solid particle trajectories have contributed to the advanced designs and coatings available. The range of availability improvement is dependent on the type of upgrade. The addition of more stages offers the greater availability improvement of the rotor body and inner casing.	0.55%	0.73%	0.90%
Reliability	The HP turbine has a very good reliability history however there are opportunities for minor reliability improvements. Failures are reduced with upgrades in materials and special coatings. The HP steam path upgrade will not affect the reliability of other systems. Upgrades that include the replacement of the rotor would have a significantly higher cost but would decrease the risk of rotor bore and dovetail fir cracking. The values show are the actual EFOR improvement (not a percent of EFOR).	0.01%	0.16%	1.50%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	HP Turbine			
Project Title:	HP Turbine Replacement			
Project Description				
Purpose	The purpose of this project is to replace the HP turbine rotor and HP turbine diaphragms to restore it to design conditions.			
Project Description	<p>HP turbine efficiency deteriorates over time, and an increase in maintenance costs occur. Replacement of the HP turbine will result in a more efficient HP turbine section. The new HP turbine rotor and diaphragms may be more efficient than the original design due to design upgrades the OEMs have recently incorporated.</p> <p>This project will involve replacement of the HP turbine rotor and diaphragms with like components. The original casings will be reused. More advanced computational fluid dynamics have led to greater efficiency and decreased losses in steam turbines.</p>			
Qualifications	Power plant operators with aging units and units with increased performance degradation should consider this project. Replacement of the HP turbine will result in an increase in machine life and an increase in unit capacity. The resultant higher efficiency of the HP turbine may decrease the capacity of rotors downstream. This factor needs to be considered before implementing this change as starving units downstream may result in a smaller net output.			
Industry Experience	Power plant operators with damaged HP turbines and HP turbines with increased performance degradation have performed this project. Additionally, power plant operators wanting an increase in capacity without boiler modifications may be able to implement a turbine replacement and avoid a New Source Review (NSR). Current lead time (2008) for an HP turbine replacement can exceed 24 months.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect heat rate improvements due to reversing unit degradation while utilizing modern steam turbine design to decrease leakage losses and stage losses. Heat rate improvement depends on the design and condition of the unit. Older designs with higher degrees of performance degradation will realize the greatest heat rate improvements.	0.25%	0.35%	0.50%
Aux Power Reduction	No change.	0.00	0.00	0.00
Capacity	HP turbine replacements will result in an increased capacity due to more efficient energy utilization. Net capacity improvements may be less than HP turbine capacity improvements due to decreased energy available in the steam to the IP and LP turbines. Capacity improvements are dependent on unit design and condition. Older units with higher degrees of performance degradation will realize the greatest capacity improvement from an HP turbine replacement.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Material costs and availability are issues for all vendors, resulting in high HP turbine replacement costs. Capital costs tend to be higher for older machines due to the degree of modification necessary to accommodate a new rotor and diaphragms.	\$5,000,000	\$7,500,000	\$10,000,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	Maintenance costs may increase as seals wear over time and would necessitate replacement. Replacement of tip seals is relatively easy during major outages, and would result in 200 to 300 additional man-hours.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The HP turbine replacement should increase availability of the unit due to a decrease in HP turbine planned outages.	0.00%	0.00%	0.00%
Reliability	This project would generally increase unit reliability by alleviating problems associated with degradation of the HP turbine hardware. Newer and better maintained systems would see the least improvement and by contrast older systems that are experiencing more problems will recognize more significant improvements.	0.02%	0.10%	0.20%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	IP Turbine			
Project Title:	IP Steam Seal Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the IP turbine steam seals to minimize leakage losses and improve efficiency. This project will improve heat rate by minimizing steam leakage losses across the turbine blades and between the stationary nozzles and rotor. The effect on turbine performance is two-fold. With this leakage less steam is driving the rotating blades. The leaking steam, upon re-entry to the normal steam path disturbs the flow pattern adding swirl and forcing some of the steam to enter the next row of blades or stationary nozzles at non-optimal angles. By minimizing losses, more steam will be available to power the turbine, resulting in increased efficiency and capacity.			
Project Description	Leakage losses represent the greatest portion of turbine stage losses. The losses increase as the turbine packing and turbine diaphragm spill strips wear. A large amount of these losses are recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the IP turbine major inspection.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. If the turbine blade covers require redesign, the rotor will have to be sent to the supplier's shop. Turbine packing should be replaced whenever wear exceeds OEM recommendations, and accurate turbine alignment will reduce leakage losses. Packing and spill strip replacement can be performed at the plant site with the IP rotor and diaphragms removed from the unit.			
Industry Experience	There is extensive industry experience with steam seal upgrades. All major OEMs and several third party vendors offer steam seal upgrades as a standard efficiency improvement.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase IP turbine efficiency. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses.	0.10%	0.20%	0.50%
Aux Power Reduction	No change.	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit by a small percentage. Capacity improvements depend on the amount of deterioration the unit had suffered over its life cycle, and the previous turbine stage blade cover design.	0.00%	0.20%	1.00%
Costs				
Capital Investment	Capital investment will vary based on current equipment configuration and condition. Older HP turbine designs with uncovered buckets would lead to higher capital costs. Vendor availability and the current state of the power generation repair market could also affect costs.	\$500,000	\$1,000,000	\$10,000,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	Maintenance costs may increase as seals tend to wear over time and would necessitate replacement. Replacement of tip seals is relatively easy during major outages, and would result in 200 to 300 additional man-hours. Though a real cost savings the value of extending future outages is very unit and system specific. Therefore, an estimate of the annual cost savings is not included. However individual companies can and should evaluate the benefit of the postponement of a major outage.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No additional outage time is expected.	0.00%	0.00%	0.00%
Reliability	History has proven the IP turbine to be extremely reliable with very few incidents of forced outages. This is the reason there are no EFOR improvements noted for this project.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. Note that discussions with Turbine Engineering indicate that the benefit of the seal upgrades may be questionable based on their past experience.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	IP Turbine			
Project Title:	IP Steam Path Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the IP turbine to a more efficient design. This project will improve heat rate, capacity, and efficiency by adding advanced steam seals, upgraded nozzle and turbine blade profiles, upgrading materials and coatings. An improved aerodynamic design is utilized which results in decreased profile and secondary losses.			
Project Description	IP steam turbine upgrades are readily available from OEM vendors. The IP upgrade retrofits the current unit with new technology rotating blades and stationary nozzles. This is known as an advanced design steam path upgrade (ADSP). All turbine blades and diaphragm nozzles are fitted with advanced design tip seals. The steam path upgrade requires 1-2 years advanced planning to allow the vendor time to implement the design, and manufacture the parts.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. Steam path upgrades are an excellent alternative to retiring older units in favor of new generating equipment. Steam path upgrades allow power plant operators to extend the life of units beyond the 40 year design limit. Steam path upgrades are especially useful for power plant operators considering plant upgrades without re-permitting. This upgrade would eliminate the need for steam seal upgrades as these upgrades are included in the retrofit.			
Industry Experience	There is extensive industry experience with HP turbine steam path upgrades. Power plant operators enjoy the fast capital investment return and increased plant efficiency gains usually without the necessity of re-permitting. The design life of the upgrades is equal or greater than the design life of the plant. The advanced design steam path upgrade has been available from vendors since 1995.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect a significant heat rate improvement with the IP steam path upgrade. The advanced steam path with advanced sealing and advanced turbine blade and nozzle profiles greatly increases the efficiency of the IP turbine. Leakage losses, secondary losses, and profile losses, are all reduced with this upgrade. The increased efficiency leads to an increased unit capacity and decreased heat rate.	0.40%	0.50%	0.60%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit, with the amount of capacity improvement dependent on several factors. Aging units and units with increased capacity deterioration can expect greater capacity improvement. Capacity improvement is a function of unit size. Generator maximum rating needs to be considered. Efficiency of the IP turbine may affect the output of the LP turbine due to a decrease in energy available in the steam.	0.40%	0.70%	1.00%
Costs				
Capital Investment	Capital investment will depend on whether the upgrade involves just turbine blades and diaphragms or the entire rotor assembly. Rotor replacement represents approximately 80% of the upgrade cost. Rotor conditions should be evaluated when selecting the type of upgrade.	\$3,000,000	\$5,000,000	\$8,000,000
Operating Costs	The IP steam path upgrade would not change operating costs for the unit. No additional operations checks or inspections will be necessary. DCS upgrades in conjunction with the IP steam path upgrade may reduce operations costs.	\$0	\$0	\$0
Maintenance Costs	The IP steam path upgrade can extend the major overhaul schedule to ten years. This decreased planned outage frequency will reduce the overall maintenance costs of the IP turbine. In a 30 year span, two major planned outages will be eliminated. The real costs savings depends on the value of extending future outages and is unit and system specific. Therefore, an estimate of the annual cost savings is not included. However, individual power plant operators can and should evaluate the benefit of the postponement of a major outage.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The IP steam path upgrade extends the major maintenance cycle from six to ten years. Advanced nozzle and turbine blade designs result in minimizing solid particle erosion are utilized. Computer modeling of solid particle trajectories have contributed to the advanced designs and coatings available.	0.55%	0.73%	0.90%
Reliability	History has proven the IP turbine to be extremely reliable with very few incidents of forced outages. This is the reason there are no EFOR improvements noted for this project.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	IP Turbine			
Project Title:	IP Turbine Replacement			
Project Description				
Purpose	The purpose of this project is to replace the IP turbine rotor and IP turbine diaphragms to restore it to design conditions.			
Project Description	IP turbine efficiency deteriorates over time, and an increase in maintenance costs occur. Replacement of the IP turbine will result in a more efficient IP turbine section. The new IP turbine rotor and diaphragms may be more efficient than the original design due to design upgrades the OEMs have recently incorporated. This project will involve replacement of the IP turbine rotor and diaphragms with like components. The original casings will be reused. More advanced computational fluid dynamics have led to greater efficiency and decreased losses in steam turbines.			
Qualifications	Power plant operators with aging units and units with increased performance degradation should consider this project. Replacement of the IP turbine will result in an increase in machine life and an increase in unit capacity. The resultant higher efficiency of the IP turbine may decrease the capacity of the LP Turbine. This factor needs to be considered before implementing this change as starving units downstream may result in a smaller net output.			
Industry Experience	Power plant operators with damaged IP turbines and IP turbines with increased performance degradation have performed this project. Additionally, power plant operators wanting an increase in capacity without boiler modifications may be able to implement a turbine replacement and avoid a New Source Review (NSR). Current lead time (2008) for an IP turbine replacement can exceed 18 months.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect heat rate improvements due to reversing unit degradation while utilizing modern steam turbine design to decrease leakage losses and stage losses. Heat rate improvement depends on the design and condition of the unit. Older designs with higher degrees of performance degradation will realize the greatest heat rate improvements.	0.10%	0.25%	0.40%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	IP turbine replacements will result in an increased capacity due to more efficient energy utilization. Net capacity improvements may be less than IP turbine capacity improvements due to decreased energy available in the steam to the LP turbines. Values shown are net capacity improvements for replacement of the IP turbine only.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Material costs and availability are issues for all vendors, resulting in high IP turbine replacement costs. Capital costs tend to be higher for older machines due to the degree of modification necessary to accommodate a new rotor and diaphragms.	\$3,000,000	\$5,000,000	\$8,000,000
Operating Costs	No change	\$0	\$0	\$0
Maintenance Costs	No additional maintenance costs for the IP turbine are expected as a result of this project. This project would generally be scheduled concurrent with the next planned IP turbine maintenance.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The IP turbine replacement should increase availability of the unit due to a decrease in IP turbine planned outages.	0.00%	0.00%	0.00%
Reliability	History has proven the IP turbine to be extremely reliable with very few incidents of forced outages. This is the reason there are no EFOR improvements noted for this project.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	LP Turbine			
Project Title:	LP Steam Seal Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the LP turbine steam seals to minimize leakage losses and improve efficiency. This project will improve heat rate by minimizing steam leakage losses across the turbine blades and between the stationary nozzles and rotor. The effect on turbine performance is two-fold. With this leakage less steam is driving the rotating blades. The leaking steam, upon re-entry to the normal steam path disturbs the flow pattern adding swirl and forcing some of the steam to enter the next row of blades or stationary nozzles at non-optimal angles. By minimizing losses, more steam will be available to power the turbine, resulting in increased efficiency and capacity.			
Project Description	Leakage losses represent the greatest portion of turbine stage losses. The losses increase as the turbine packing and turbine diaphragm spill strips wear. A large amount of these losses are recoverable with packing replacement, spill strip upgrades, and nozzle balance hole optimization. New turbine blade cover and nozzle spill strip designs are available which greatly reduce turbine blade tip leakage losses. New interstage and end packing will reduce packing leakage losses, resulting in more steam available to power the turbine blades. Retractable packing and brush seal packing designs are available from various manufacturers, which aim to reduce leakage losses even further from original designs. This upgrade can be performed at the LP turbine major inspection.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. If the turbine blade covers require redesign, the rotor will have to be sent to the supplier's shop. Turbine packing should be replaced whenever wear exceeds OEM recommendations, and accurate turbine alignment will reduce leakage losses. Packing and spill strip replacement can be performed at the plant site with the LP rotor and diaphragms removed from the unit.			
Industry Experience	There is extensive industry experience with steam seal upgrades. All major OEMs and several third party vendors offer steam seal upgrades as a standard efficiency improvement. Lead times may be as long as 12 months. Power plant operators have experienced good experience with retractable brush seals over the years.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	The steam seal upgrade will improve the plant heat rate by allocating more steam to power the turbine. This upgrade will tend to decrease heat rate and increase LP turbine efficiency. The degree of improvement will vary based on unit size and the previous turbine stage blade cover design. Older designs will realize greater improvements due to a greater reduction in turbine blade tip leakage losses. The new gland seals also reduce the air in leakage around the shaft. The improved gland seal reduce the amount of air that ultimately enters the condenser. Air in the condenser tends to raise back pressure and negatively impact heat rate. Reducing the air inleakage through improved seals can decrease (improve) back pressure by 0.2" - 0.8" Hg with a corresponding heat rate improvement of near 1.0%. Excessive condenser air inleakage may cause elevated levels of dissolved oxygen in the condensate and feedwater, increasing the corrosion potential. Units with reasonably good steam seals would realize considerably less improvement.	0.10%	0.20%	0.50%
Aux Power Reduction	No change.	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit by a small percentage. Capacity improvements depend on the amount of deterioration the unit had suffered over it's life cycle, and the previous turbine stage blade cover design.	0.10%	0.30%	0.70%
Costs				
Capital Investment	Capital investment will vary based on current equipment configuration and condition. Older LP turbine designs with uncovered buckets would lead to higher capital costs. Vendor availability and the current state of the power generation repair market could also affect costs.	\$500,000	\$750,000	\$1,200,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	Maintenance costs may increase as seals tend to wear over time and would necessitate replacement. Replacement of tip seals is relatively easy during major outages, and would results in 200 to 300 additional man-hours. Seal replacement would occur based on component inspections and wear measurements that are discovered below design operating specifications. These inspections would take place on a six to eight year major outage cycle. Assuming 300 man-hours at \$150 per hour over an eight (8) year outage cycle the annual cost would be \$5625.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No additional outage time is expected.	0.00%	0.00%	0.00%
Reliability	Only minor changes in reliability are expected. The typical reliability is very small therefore the potential for improvement is limited.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. Note that discussions with Turbine Engineering indicate that the benefit of the seal upgrades may be questionable based on their past experience.				

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Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	LP Turbine			
Project Title:	LP Turbine Last Stage Buckets			
Project Description				
Purpose	The last stage buckets are responsible for approximately 10% of the turbine's total output. Redesign of the last stage buckets, including increasing length, reduces exhaust loss by increasing the amount of energy removed from the steam. This increases capacity and decreases heat rate.			
Project Description	The project includes replacing the last stage LP turbine buckets or blades with new technology, longer blades. Replacing the last stage diaphragm is also recommended to maximize efficiency gain. Redesigned last stage buckets ensure uniform flow distribution. The new design also utilizes bucket covers. Covered buckets reduce leakage losses and maximize steam energy utilization. Longer last stage buckets reduce exhaust losses by maximizing the amount of energy extracted from the steam. This is done by increasing the area of the last stage to reduce exhaust velocity.			
Qualifications	Performance gains from replacing the last stage buckets is dependent on where the unit operates on its exhaust loss curve. If the unit operates at low condenser pressures and higher mass flows, the turbine most likely operates high on the exhaust loss curve and would benefit from the modifications. With low mass flows and high condenser pressures, the unit most likely operates low on the exhaust loss curve, and this modification would hurt performance.			
Industry Experience	OEMS have been increasing last stage bucket length since the 1970s and continue to do so today. Lead times for orders for new last stage buckets can be as long as 18 months.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	This project improves plant heat rate by minimizing exhaust losses. Heat rate improvements will vary based on the current last stage design, the length of bucket to be installed, and whether or not the customer would like to replace the last stage diaphragm. Replacement of the last stage diaphragm is often required.	1.00%	1.50%	3.00%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	This project will increase the capacity of the unit. With longer advanced design last stage buckets, power plant operators have realized capacity improvements of up to 3%.	1.00%	1.50%	3.00%
Costs				
Capital Investment	Capital investment will vary based on current equipment configuration and condition. Older LP turbine designs with uncovered buckets would lead to higher capital costs. Vendor availability and the current state of the power generation repair market could affect costs.	\$2,000,000	\$3,000,000	\$4,000,000
Operating Costs	No change	\$0	\$0	\$0
Maintenance Costs	The LP last stage bucket upgrade is expected to decrease maintenance costs due to advanced materials that are less susceptible to erosion.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	A major outage on the LP turbine would be necessary to complete this project. The retrofit may require shipping the LP turbine to the OEM shop for balancing. This retrofit would not affect the long term availability of the unit.	0.00%	0.00%	0.00%
Reliability	Advances in materials and special coatings are expected to provide improvements in performance as well as minor increase in reliability. OEMs have increased the length of the last stage buckets and blades with better thermal properties. These design changes are expected to have a positive impact on reliability.	0.03%	0.07%	0.20%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	LP Turbine			
Project Title:	LP Steam Path Upgrade			
Project Description				
Purpose	The purpose of this project is to upgrade the LP turbine to a more efficient design. This project will improve heat rate, capacity, and efficiency by adding advanced steam seals, upgraded nozzle and turbine blade profiles, upgrading materials and coatings. An improved aerodynamic design is utilized which results in decreased profile and secondary losses.			
Project Description	LP steam turbine upgrades are readily available from OEM vendors. The LP upgrade retrofits the current units with new technology rotating blades and stationary nozzles. This is known as an advanced design stem path upgrade (ADSP). All turbine blades and diaphragm nozzles are fitted with advanced design tip seals. The steam path upgrade requires 1-2 years advanced planning to allow the vendor time to implement the design and manufacture the parts.			
Qualifications	Power plant operators with aging units and increased performance degradation should consider this upgrade. Steam path upgrades are an excellent alternative to retiring older units in favor of new generating equipment. Steam path upgrades allow power plant operators to extend the life of the units beyond the 40 year design limit. Steam path upgrades are especially useful for power plant operators considering plant upgrades without re-permitting. This upgrade would eliminate the need for steam seal upgrades as these are included in the retrofit.			
Industry Experience	There is extensive industry experience with LP turbine steam path upgrades. Power plant operators enjoy the fast capital investment return and increased plant efficiency gains usually without the necessity of re-permitting. The design life of the upgrades is equal or greater than the design life of the plant. The advanced design steam path upgrade has been available through vendors since 1995.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect a significant heat rate improvement with the LP steam path upgrade. The advanced steam path with advanced sealing and advanced turbine blade and nozzle profiles greatly increases the efficiency of the LP turbine. Leakage losses, secondary losses, and profile losses, are all reduced with this upgrade. The increased efficiency leads to an increased unit capacity and decreased heat rate.	1.55%	2.15%	3.75%
Aux Power Reduction	No change.	0.00	0.00	0.00
Capacity	This upgrade will increase the capacity of the unit, with the amount of capacity improvement dependent on several factors. Aging units and units with increased capacity deterioration can expect greater capacity improvement. Capacity improvement is a function of unit size. Actual operating exhaust pressure will also affect the capacity improvement. Generator maximum rating needs to be considered.	1.55%	2.15%	4.00%
Costs				
Capital Investment	Capital costs for LP steam path upgrades tend to vary significantly based on the type of upgrade. Higher costs are expected when replacing the rotor versus replacing only turbine rotating blades and diaphragms. Rotor condition should be analyzed when selecting the type of upgrade.	\$5,000,000	\$8,000,000	\$16,000,000
Operating Costs	The LP steam path upgrade would not change operating costs for the unit. No additional operations checks or inspections will be necessary. DCS upgrades in conjunction with the LP steam path upgrade may reduce operations costs.	\$0	\$0	\$0
Maintenance Costs	The LP steam path upgrade can extend the major overhaul schedule to ten years. This decreased planned outage frequency will reduce the overall maintenance costs of the LP turbine. In a 30 year span, two major planned outages will be eliminated. The real costs savings depends on the value of extending future outages and is unit and system specific. Therefore, an estimate of the annual cost savings is not included. However, individual power plant operators can and should evaluate the benefit of the postponement of a major outage.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The LP steam path upgrade extends the major maintenance cycle from six to ten years.	0.55%	0.73%	0.90%
Reliability	Improvements in the steam path from better and more efficient design of rotating and stationary components can have a positive impact on the unit reliability. This impact is limited. Review of GADS data for the unit in question, in comparison to industry data, will help identify the potential improvement specifically by examining the upper (worst) quartile performers in the GADS data. These units would be indicative of the performance of units that have allowed the LP conditions to deteriorate.	0.05%	0.19%	0.40%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. The above estimates combine two of the EPRI projects (LP Turbine Last Stage Buckets and LP Steam Path Upgrade).				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	LP Turbine			
Project Title:	LP Turbine Replacement			
Project Description				
Purpose	The purpose of this project is to replace the LP turbine rotor and LP turbine diaphragms to restore it to design conditions.			
Project Description	LP turbine efficiency deteriorates over time, and an increase in maintenance costs occur. Replacement of the LP turbine will result in a more efficient LP turbine section. The new LP turbine rotor and diaphragms may be more efficient than the original design due to design upgrades the OEMs have recently incorporated. This project will involve replacement of the LP turbine rotor and diaphragms with like components. The original casings will be reused. More advanced computational fluid dynamics have led to greater efficiency and decreased losses in steam turbines.			
Qualifications	Power plant operators with aging units and units with increased performance degradation should consider this project. Replacement of the LP turbine will result in an increase in machine life and an increase in unit capacity.			
Industry Experience	Power plant operators with damaged LP turbines and LP turbines with increased performance degradation have performed this project. Additionally, power plant operators wanting an increase in capacity without boiler modifications may be able to implement a turbine replacement and avoid a New Source Review (NSR). Current lead time (2008) for an LP turbine replacement can exceed 18 months.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Power plant operators can expect heat rate improvements due to reversing unit degradation while utilizing modern steam turbine design to decrease leakage losses and stage losses. Heat rate improvement depends on the design and condition of the unit. Older designs with higher degrees of performance degradation will realize the greatest heat rate improvements.	0.10%	0.25%	0.40%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	LP turbine replacements will result in an increased capacity due to more efficient energy utilization. Capacity improvements are dependent on unit design and condition. Older units with higher degrees of performance degradation will realize the greatest capacity improvement from an LP turbine replacement.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Material costs and availability are issues for all vendors, resulting in high LP turbine replacement costs. Capital costs tend to be higher for older machines due to the degree of modification necessary to accommodate a new rotor and diaphragms.	\$6,000,000	\$8,500,000	\$11,000,000
Operating Costs	No change	\$0	\$0	\$0
Maintenance Costs	Maintenance costs are expected to decrease due to improved overall turbine condition and decreased outages due to LP turbine issues.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The LP steam path upgrade extends the major maintenance cycle from six to ten years. If the plant operator is performing turbine outages on a component basis (HP, separate from IP or LP) then this could allow for an extension. Otherwise no change due to this project alone would be expected.	0.00%	0.00%	0.00%
Reliability	The LP turbine replacement will increase unit reliability. Problems associated with degradation of LP turbine hardware will be alleviated.	0.02%	0.10%	0.20%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Steam Turbine			
Project Title:	Exhaust Hood Steam Guide Modification			
Project Description				
Purpose	Modify the LP turbine exhaust hood steam guide based on results of computational fluid dynamic (CFD) flow modeling to minimize losses and improve turbine efficiency.			
Project Description	Poor aerodynamic design of the exhaust hood can cause a large pressure drop between the last stage turbine blades and the hood exit. Improved exhaust hood design can reduce that pressure drop between the last stage blades and the exhaust hood exit, resulting in more energy available to produce power. A CFD analysis should be conducted to determine the optimum design modification to the exhaust hood steam guide to improve steam path efficiency.			
Qualifications	Applicable to all steam plants with condensing turbines. This modification is generally not cost effective for units less than 20 years old due to improved exhaust hood steam guide aerodynamic design in newer models. Refer to EPRI Study TR-109225 for more information.			
Industry Experience	Exhaust hood steam guide modifications are offered by several OEMs, and are currently used in last stage turbine blade upgrades.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Heat rate improvements are realized through an increase in LP turbine capacity.	0.00%	0.00%	0.00%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	Exhaust hood steam guide modifications result in an increase in last stage efficiency. Range of capacity improvement is dependent on the vintage of LP turbine and the design of the exhaust hood. Several OEMs can provide performance predictions based on exhaust hood flow modeling.	0.25%	0.50%	1.00%
Costs				
Capital Investment	Capital investment varies based on configuration and vendor. The range of values is dependent on the degree of modification necessary to the flow guide and exhaust hood.	\$150,000	\$500,000	\$2,000,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	No change.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	This project may decrease plant availability during the implementation year as this project requires a custom modification and may extend the turbine outage. Overall availability is expected to remain the unchanged.	0.00%	0.00%	0.00%
Reliability	This modification may increase unit reliability. An improved exhaust hood steam guide can decelerate steam flow, reducing the possibility of flow-generated noise and vibration in the condenser tubes.	0.00%	0.02%	0.05%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Generator			
Project Title:	Rewind the Generator Rotor & Stator			
Project Description				
Purpose	The purpose of this project is to improve the efficiency and reliability of the generator. This project addresses the needs for taking action to increase the incremental MW output of the generator by improving current flow and generator cooling properties.			
Project Description	Rewinding the generator requires that the unit be removed from service (eg a planned outage). Improvements in technology, replacement parts and maintenance procedures can enhance the efficiency of the existing generator operating with the same input. Such a project would only be undertaken when rewinding the generator due to reliability concerns driving the generator outage decision. Work scope includes the following: The work begins with the opening of the generator and removal of the generator rotor. A complete visual inspection of the stator and rotor is performed. The stator work involves removal of the old bars and complete rewind of the generator stator. The existing end windings support system and winding blocks are replaced, new copper is installed, and thinner mica insulation is installed with much better thermal properties. Thinner insulation allows for the installation of more copper which improves current flow that operates in a cooler environment. The generator rotor is removed from the stator and shipped to a rewind facility. There the retaining rings and the copper winding strands, existing leads, field wedging and collector rings are expected.			
Qualifications	The generator rotor is removed from the stator and shipped usually to the OEM shop. There the retaining rings and the copper winding strands are replaced, the existing leads are replaced, the field wedging is replaced and collector rings are replaced.			
Industry Experience	Rewinding the generator is a common practice in the industry. Utilities pursue this option to extend the life of the existing generator and improve reliability. Advances in generator technology and new materials now allow for owners to make modifications that will increase the MW output of the generator. Currently (2008) lead time for new			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	No change in heat rate is expected, instead the improvement is expected to occur in terms of additional capacity.	0.00%	0.00%	0.00%
Aux Power Reduction	No change	0.00	0.00	0.00
Capacity	OEM analysis of a 935 MW generator concluded that 0.214 MW incremental capacity was achievable after rewinding the generator. The increase is a function of better insulation, the unit operating at lower temperatures, and improved current flow.	0.01%	0.02%	0.04%
Costs				
Capital Investment	The capital investment required is driven by the generator capacity size, design, and cost of new copper, end turn modifications, and lead time to manufacture new strands. The current and future operating mode of the unit will also be a factor and will have a direct affect on the cost benefit. This project would only be cost justified when the generator age and condition suggest that long term reliability could be in question. In that instance the reliability improvement drives the project much more than the capacity improvement.	\$10,000,000	\$14,000,000	\$18,000,000
Operating Costs	Because of the incremental efficiency improvement, the unit operating costs should result in lower CO2 production without increasing the fuel burn rate.	\$0	\$0	\$0
Maintenance Costs	Rewind of the generator and stator are typically performed to enhance the stator and rotor reliability. Improvements in materials and the ability to decrease the amount of heat that the unit produces enables incremental increases in the unit production capacity without additional maintenance expenses.	-\$5,000	-\$20,000	-\$50,000
Availability and Reliability Issues				
Availability	The outage time to complete the rewind is expected to take 10 - 12 weeks. This could result in a one time increase in the planned outage but after the project is completed no change in availability would be expected.	0.00%	0.00%	0.00%
Reliability	The 5% improvement is a function of the mitigation of a catastrophic failure and is not plausible in most cases. However, the primary driver for this project will be to mitigate the probability of a catastrophic failure. Such a failure is (generally) only a concern for units that have seen many years of service, a high number of thermal cycles and/or have experienced some specific issue that causes long term reliability to be in question.	0.25%	0.50%	1.50%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Generator			
Project Title:	Increase Hydrogen Purity			
Project Description				
Purpose	The purpose of this project is to improve the hydrogen purity thereby reducing windage losses. The purity of hydrogen has a direct effect on the generator efficiency. The amount of moisture and dew point also has an effect on the windings and reliability of the unit. Maintaining the recommended/constant hydrogen pressure also contributes to the reliable operation of the generator.			
Project Description	The project involves installing a onsite hydrogen generator to produce hydrogen on demand and keep the dew low inside the generator. This project focuses on improving and sustaining the hydrogen purity within a range of 98-99% and a lower dew point. The project involves a system design review, developing methods for measuring and monitoring the continuous hydrogen purity. The hardware would be installed during a scheduled outage. The unit would produce and supply hydrogen to the generator on an as needed basis based on the condition of the hydrogen inside the generator. Installation of the unit reduces the need for onsite hydrogen cylinders and transportation.			
Qualifications	This project is not viable for air cooled generators and is reserved for hydrogen cooled generators.			
Industry Experience	There are several US and international utilities that have installed permanent hydrogen purity systems. According to the OEM and utilities where the systems were installed the operator did see improvement in the generator output.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Heat rate improvement is anticipated from the incremental increase in the generator capacity improvements. The generator is the primary equipment that is affected resulting from the stator and field operating in a better controlled environment with less windage losses. The improvements that are obtained can be lessened with the infiltration of air and moisture entering the generator from impurities in the oil supply.	0.00%	0.00%	0.00%
Aux Power Reduction	There is no aux power reduction associated with this project. The unit will actually result in a small increase of aux power.	-0.008	-0.012	-0.024
Capacity	According to the vendor, an 800 MW unit with a 1% increase in hydrogen purity will realize a corresponding 366 kW increase in power output. Therefore a 3% increase in hydrogen purity will yield an additional 1 MW output without increasing fuel consumption.	0.02%	0.10%	0.50%
Costs				
Capital Investment	The capital investment would be offset by alleviating the expense for the transport of bottled hydrogen cylinders stored at the plant. Studies suggested that the capital investment for one 800 MW unit is \$400,000.	\$225,000	\$350,000	\$600,000
Operating Costs	The hydrogen generator will require a dedicated source of demineralized water and auxiliary power. For the reference case the unit is estimated to require approximately 20 gal/day of demineralized water in addition to 26 kWh for every 100 cubic feet of hydrogen produced.	-\$1,000	-\$2,000	-\$3,000
Maintenance Costs	The system will require routine maintenance, however, no adverse effects are anticipated as a result of additional hydrogen purity sensors, controls and safety monitoring equipment.	\$5,000	\$10,000	\$15,000
Availability and Reliability Issues				
Availability	The equipment can be installed during a planned turbine/generator outage. Currently no additional outage time is expected.	0.00%	0.00%	0.00%
Reliability	Sustaining the generator casing's pressure, purity, and dew point should enhance the reliability of the generator. As a batch process temporary unavailability of the hydrogen generator can be addressed from storage. As a back up delivery of hydrogen cylinders could be utilized though the unit capacity improvement would be negated.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Economizer			
Project Title:	Economizer Retrofit			
Project Description				
Purpose	Replace or retrofit the economizer with an economizer that is designed to better support the operating conditions and fuels burned in the boiler.			
Project Description	With an increasing shift to lower quality fuels in recent years, continuous fin surface (CFS) economizers are more susceptible to plugging and fly ash erosion. This can lead to increased stack temperatures and a decrease in cycle efficiency. Installing a retrofitted economizer designed to operate efficiently with lower quality fuels will improve boiler efficiency. In order to increase tube spacing to allow for better cleaning, additional heat transfer surface is required to maintain design economizer performance.			
Qualifications	This project would be applicable to units experiencing economizer ash plugging problems, and decreased cycle efficiency. A staggered CFS economizer with severe ash pluggage may not see a benefit from the finned surface as they are insulated with fly ash. A thorough cost/benefit analysis should be conducted prior to issuing RFPs. A New Source Review may be triggered with this retrofit.			
Industry Experience	There is extensive industry experience with economizer retrofits.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	The heat rate benefit from this retrofit is dependent on the degree of economizer efficiency reduction experienced. Retrofitting the CFS economizer by decreasing the number of tubes per row will decrease design efficiency, but may increase current operating efficiency by decreasing ash pluggage. Similarly, retrofitting a staggered CFS economizer with a bare tube in-line economizer may reduce heat transfer from design, but increase heat transfer from current operating conditions. Design heat transfer can be reached by increasing the number of passes.	0.00%	1.00%	2.00%
Aux Power Reduction	No change.	0.000	0.000	0.000
Capacity	Capacity will increase as a result of heat rate improvement.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Capital cost will vary depending on the configuration of the boiler, accessibility, modifications required, and various options available with retrofitted economizers.	\$1,000,000	\$2,000,000	\$4,000,000
Operating Costs	No additional operating cost is anticipated.	\$0	\$0	\$0
Maintenance Costs	Maintenance costs would tend to decrease as ash pluggage of the economizer would be reduced.	-\$10,000	-\$20,000	-\$30,000
Availability and Reliability Issues				
Availability	This retrofit would increase the boiler major overhaul length, and would decrease availability during the installation year. However, long term availability will remain the same or improve.	0.00%	0.20%	1.00%
Reliability	No change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Boiler			
Project Title:	Water Cannons			
Project Description				
Purpose	The project involves the installation of water cannons to maintain and keep the water wall tube surfaces clean.			
Project Description	This capital project involves installing high pressure water cannons in predetermined areas along the furnace wall. Water cannons use a blast of high pressure water and generally clean a 30' x 30' area in 10 - 20 seconds. Water cannons deploy approximately 150 - 250 gallons/minute depending on boiler size at a water pressure ranging between 250 and 350 psi. Installation typically takes about two weeks. That includes mechanical work, installation controls, wiring and testing.			
Qualifications	Retractable wall blowers are often ineffective and cover limited cleaning areas approximately 10' in diameter. Furthermore utilities switching from bituminous coal to sub bituminous PRB coal are more susceptible to tube fouling because of highly reflective whitish ash deposits common to PRB coal. The reflective nature of PRB coal increases exit temperatures and makes removal of PRB deposits very difficult. PRB is high in sodium that greatly increase fouling in the convection pass and may require additional cleaning.			
Industry Experience	The introduction of water cannons as a furnace cleaning option dates back to 1988. Systems are commercially available today.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Increased cleanliness of the boiler surface areas will improve heat absorption. The cleanliness of the boiler is a function of the type of fuel that is fired in the boiler. Certain coals have chemical properties that foul the boiler tubes and are difficult to clean, which affects the plant heat rate requiring additional fuel to be burned. This is one reason why the heat rate improvement will vary.	0.50%	1.00%	2.00%
Aux Power Reduction	No change	0.10	0.30	0.50
Capacity	Increased cleanliness of the boiler surface will improve heat absorption. Increased absorption allows for incremental capacity gains.	0.00%	0.00%	0.00%
Costs				
Capital Investment	The capital costs for this project generally include soot blower control systems, heat flux monitors, a "window" in the boiler tube wall, some structural steel, and engineering. Onsite installation construction costs include mechanical and electrical contractors to install the water cannons and make ties into the plant support systems. The expected range of capital costs were extracted from actual vendor proposals and are a function the bidder's proprietary skid mounted equipment and designs. The range of capital costs are unit specific and vary based on the number of cannons. accessibility to make water supply and air connection, materials, vendor engineering estimates for wall openings and locations on the boilers, infrared cameras, controls, start up inventory, and fabrication processes and techniques. The representative size of the boiler in this case was in the range of 400-500 MWs.	\$1,600,000	\$1,800,000	\$2,000,000
Operating Costs	Operator training on the use and operation of the water cannons is a one time cost. The cost of supply water and control air is expected to be marginal. The water cannons require a clean water source and as a result there will be additional water and chemical costs.	\$1,000	\$1,500	\$2,500
Maintenance Costs	Annual routine maintenance will be required to test and replace bearings, seals, valves, nozzles, motors and controls. The range of annual costs is a function of frequency of water cannon cleaning cycles and effects of falling slag inside the boiler coming in contact with cleaning apparatus.	\$5,000	\$10,000	\$15,000
Availability and Reliability Issues				
Availability	Improvements in unit operational performance will generally be evident in reliability improvements as opposed to reduced planned or maintenance outage time.	0.00%	0.00%	0.00%
Reliability	Comprehensive soot blower studies have shown that properly controlled water cannons can reduce the number of tube leaks by 50% or more. Eliminating the number of tube related incidents will improve unit performance. However, water cannon that are operated manually and excessively can result in thermal fatigue from the thermal shock water blasting clean tube surfaces could that can increase forced outage tube leaks. Water cannons that are controlled automatically with thermal flux and strain gauges reduce the cleaning cycle and increase the boiler tube life.	0.10%	0.50%	2.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Boiler			
Project Title:	Automate Boiler Drains			
Project Description				
Purpose	Automation of the operation of boiler drains will improve heat rate by eliminating the waste of heat through drains inadvertently open when they should have been closed after unit start-up.			
Project Description	Installation of automatic valve positioners will be required. After installation operating personnel will be able to control the position of these valves and eliminate excessive steam loss. A screen for the DAS should also be incorporated into this project that provides indicating lights for valve position.			
Qualifications	This project is applicable to all steam units and the cost should be cost justifiable as most of these valves are .5 to 2.5 inches.			
Industry Experience	This is industry proven and is a regular design feature on combined cycle units.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Heat rate improvement based on curtailment of steam being blown down when unnecessary. Steam available for turbine and powering generator.	0.10%	0.20%	0.35%
Aux Power Reduction	No aux power improvement, power requirements for automation will be negligible.	0.000	0.000	0.000
Capacity	No change.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Capital cost would be the purchase and installation of automatic valve operators and controls.	\$25,000	\$50,000	\$75,000
Operating Costs	Cost would slightly decrease as less make-up water would be required and water treatment chemicals would be reduced.	-\$5,000	-\$10,000	-\$15,000
Maintenance Costs	Annual maintenance of operators and calibration.	\$3,000	\$6,000	\$10,000
Availability and Reliability Issues				
Availability	No effect, can be accomplished during scheduled outage.	0.00%	0.00%	0.00%
Reliability	Installation of automatic boiler drain valves may reduce damage to baffles and spargers in the condenser, and may reduce wear on drain piping elbows. The effect on plant reliability is difficult to quantify, and should be analyzed on a plant level.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. Note that many of these valves on the UE side are already automated so that the benefit may not be as great as that shown here. In addition, the capital cost for this project appears to be low.				

Note: The addition of automated boiler drain valves was found to be much more costly than the generic estimate provided in the original EPRI report. In addition, the plants were more interested in monitoring line temperatures than automating more valves. Therefore, this project was not evaluated further for Ameren.

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Electrostatic Precipitator			
Project Title:	Variable Power Input to ESP fields			
Project Description				
Purpose	Automatically adjust power input to ESP fields based upon ash loading to reduce aux power consumption and maintain ash collection.			
Project Description	Install a variable control system to modulate the power input into the ESP fields to minimize power usage at low loads when ash loading on the ESP is reduced.			
Qualifications	Applicable only to coal fired units with ESP's.			
Industry Experience	These control systems currently exist and have been applied to ESP units.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	No change.	0.00%	0.00%	0.00%
Aux Power Reduction	Modulating power input based on ash loading will result in a decrease in auxiliary power consumption. The range of values is based upon an assumption of 600 KW required to power the ESP. A 15% reduction in ESP power can be expected from implementing this project.	0.050	0.090	0.180
Capacity	Net capacity improvement is realized through a reduction in auxiliary power.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Capital cost for this project are based on the number of transformer rectifier sets the user elects to modify. Costs are approximately \$11,000 per TR set. The expected number of TR sets is 60 for a 500 MW unit. The low value is for modifying only the forward half of the TR sets. The high value is for modifying all the TR sets.	\$330,000	\$440,000	\$660,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	Annual maintenance costs are not expected to change. Although new equipment will require maintenance, cost to maintain existing equipment is expected to decrease.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No change.	0.00%	0.00%	0.00%
Reliability	No change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Heat Rejection			
Project Title:	Condenser Retube			
Project Description				
Purpose	Significant efficiency improvements can be achieved by retubing the condenser where the condenser performance has decreased due to fouling, plugged tubes or other issues that degrade heat transfer. Improving the condenser thermal performance results in reduced back pressure, increasing output and reducing (improving) heat rate. In some cases it is advantageous to retube with a new material that is better suited to the conditions even if that material has poorer heat transfer characteristics. In those cases the improvement in reliability more than offsets the reduction in heat transfer.			
Project Description	The thermal performance of the condenser can decrease due to fouling, corrosion, and other wear related issues. These can occur on either the steam side or the water side of the tubes. The capital project would be scheduled for completion during a planned outage and will require the complete removal of the existing tubes and possible tube sheets. In some cases it is most effective to completely remove the shell from the condenser expansion joint (dog bone) to the bottom of the water box and replace the entire condenser. With regard to the replacement tube material a detailed engineering assessment will have to be conducted to identify the best tube material for the circumstances. The material with the highest heat transfer coefficient is many times not the best application.			
Qualifications	This project is viable for surface condensers that are consistently experiencing poor performance due to plugged tubes that has caused a significant number of tubes to be taken out of service. In some cases the project is justified simply by restoring the capacity lost through the long term accumulation of tube leaks. In other cases, improved condenser tube arrangements allow for better steam flow and thereby better heat transfer even with fewer or lower heat transfer coefficient tube materials.			
Industry Experience	The industry has a long history of replacing condenser tubes. Poor performance can be the result of various different failure mechanisms. These include tube erosion, tube to tube sheet connection failures as well as corrosion. In evaluating the replacement project the consideration of the tube material is a critical element of the project. Better heat transfer materials are often softer and therefore more subject to erosion and subsequent failure. Costs of raw materials is certainly a major consideration. Lower cost materials may be the most economic choice depending on the value achieved from the improved performance.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Benefits from retubing the condenser include improving the unit heat rate as well as increasing the unit output. The reduction in backpressure drives the heat rate improvement.	0.00%	0.50%	1.00%
Aux Power Reduction	No Aux power improvement is expected.	0.00	0.00	0.00
Capacity	Capacity improvement is a result of sustained reductions in back pressure. This is a function of improved heat transfer in the condenser thus allowing for a greater pressure differential across the LP turbine. The range of improvement is very much a function of the condition of the condenser before the retubing project. In large part this will just be a restoration of lost capacity because in most cases the original condenser performance would have included the capacity considered herein. However, it is possible to redesign the tube arrangement for a better steam distribution and therefore achieve better heat transfer than the original design.	0.20%	0.30%	0.40%
Costs				
Capital Investment	The capital investment estimate for retubing the condenser are in the range of \$2 to \$4 million dollars for a typical 500 MW unit. The major cost is materials in addition to construction and installation. The cost is driven by the materials, type of metal, and accessibility to the work site. Condensers are located underneath the turbine in some areas where the work space is limited. This fact comprises the number of personnel and materials than can be placed on the jobsite at one time and may affect productivity. Other factors include the increase in raw materials (metal) costs and longer delivery times.	\$2,000,000	\$3,000,000	\$5,000,000
Operating Costs	No incremental operating costs are expected.	\$0	\$0	\$0
Maintenance Costs	No increased maintenance is expected.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No change in availability is expected.	0.00%	0.00%	0.00%
Reliability	Reliability of the unit is expected to increase because of reduced outages/deratings associated with tube leaks. The range of improvements will be a function of the level of degradation tolerated up to the point of the retubing and the specific failure mechanisms.	0.75%	1.00%	2.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Condenser			
Project Title:	Condenser Online Tube Cleaning System			
Project Description				
Purpose	The purpose of this project is to reduce condenser tube fouling and scale accumulation through installation of an online tube cleaning system.			
Project Description	Install a retrievable ball tube cleaning system to periodically remove fouling from the inner surface of condenser tubes. Keeping condenser tubes free of fouling will maintain design heat transfer between the condensing steam and circulating water.			
Qualifications	This would be applicable on units with water cooled condensers. It would not be applicable on air cooled condensing units.			
Industry Experience	This has been effectively utilized on water cooled condensers for decades.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	As condenser cleanliness improves, condenser backpressure is reduced, resulting in a heat rate improvement.	0.10%	0.20%	0.30%
Aux Power Reduction	This project will negatively impact auxiliary power to a very small degree. The retrievable ball injection system will require a small amount of power for the injection pump, motor operated valves, and associated controls.	0.00	-0.01	-0.01
Capacity	Capacity benefit is a result of heat rate improvement. A capacity improvement may occur at higher loads.	0.00%	0.00%	0.10%
Costs				
Capital Investment	Capital costs depend on the vendor and the specifications of the system chosen.	\$500,000	\$650,000	\$800,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	Annual maintenance expenses are expected to increase, as new equipment will be installed with this project.	\$2,000	\$5,000	\$10,000
Availability and Reliability Issues				
Availability	The retrievable ball cleaning system can be installed during the annual boiler outage, and would not decrease unit availability. Over the long term, availability may increase due to a decrease in the need for	0.00%	0.00%	0.20%
Reliability	Installation of a retrievable ball cleaning system would reduce the occurrence of forced outages or derates due to condenser tube fouling.	0.00%	0.01%	0.05%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Condenser			
Project Title:	Water Box Vacuum Priming System			
Project Description				
Purpose	Install a vacuum priming system on all condenser water boxes to maximize the flow through the tubes and improve heat transfer.			
Project Description	Install a vacuum priming system on the inlet and outlet of the condenser water boxes to ensure the water box is continuously full, thereby assuring all condenser tubes are providing an effective cooling surface.			
Qualifications	Not applicable to air cooled condenser units.			
Industry Experience	This is a proven design effective in improving condenser performance.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	An increase in effective condenser heat transfer area leads to a decrease in condenser backpressure. The range of heat rate improvement is dependent on the increase in heat transfer surface area realized through this modification.	0.15%	0.25%	0.35%
Aux Power Reduction	Auxiliary power will increase slightly due to power demands of the vacuum priming system.	-0.02	-0.05	-0.10
Capacity	Capacity benefit is a result of heat rate improvement. A capacity improvement may occur at higher loads.	0.00%	0.00%	0.20%
Costs				
Capital Investment	Capital costs are dependent on condenser configurations and vacuum priming system specifications selected.	\$75,000	\$150,000	\$200,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	This project may increase annual maintenance costs due to maintenance required on the new equipment.	\$1,000	\$1,500	\$3,000
Availability and Reliability Issues				
Availability	No change.	0.00%	0.00%	0.00%
Reliability	No change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Heat Rejection			
Project Title:	Circulating Water Strainers			
Project Description				
Purpose	Install circulating water strainers to reduce cooling water heat exchangers tube fouling and pluggage caused by silt or debris.			
Project Description	Installation of strainers on the inlet side of the cooling water system will reduce the amount of silt and debris carried into the heat exchanger.			
Qualifications	Applicable to units with once through circulating water systems that carry a high degree of silt or debris.			
Industry Experience	This application has extensive utility industry experience in applications with river water cooling system sources.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	By reducing or eliminating silt and debris tube pluggage, the condenser and other heat exchangers maintain their expected performance.	0.50%	1.00%	2.00%
Aux Power Reduction	Auxiliary power will increase with this project due to installation of new equipment.	-0.05	-0.20	-0.30
Capacity	No change.	0.00%	0.00%	0.00%
Costs				
Capital Investment	Capital costs are dependent on the size, configuration, and location of the cooling water system.	\$200,000	\$500,000	\$2,500,000
Operating Costs	No change.	\$0	\$0	\$0
Maintenance Costs	For periodic cleaning and normal maintenance of this new component.	\$20,000	\$50,000	\$70,000
Availability and Reliability Issues				
Availability	Properly planned and executed installation should have no effect in a typical one month long planned outage.	0.00%	0.00%	0.00%
Reliability	In units with extensive erosion issues, the strainers reduce or eliminate tube leaks due to erosion, and tend to decrease EFOR associated with tube repairs.	0.10%	0.30%	0.50%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. The maximum cost was increased to provide better agreement with estimates provided by B&V for the Integrated Resource Plan.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Fuel Handling			
Project Title:	On-Site Fuel Drying			
Project Description				
Purpose	The purpose of this project is to improve the boiler efficiency by focusing on the moisture in the fuel. Reducing the moisture content in the fuel entering the plant will provide multiple benefits ranging from improved reliability, availability, and lower emissions.			
Project Description	Current coal drying projects are characterized as the construction of proprietary on-site coal drying systems that are used to reduce the moisture in the fuel. The feasibility and cost/benefits of the project are very site specific. Units that are capacity limited from coal switching tend to have the most to gain from coal drying applications. Most designs for coal drying technology attempt to utilize waste heat sources to drive moisture out of the coal before it is introduced to the mills. This may be something of a batch process or may focus on a continuous process that provides the drier fuel in real time.			
Qualifications	Coal quality greatly influences plant performance and overall generation costs. Typically a coal drying system would be most applicable to units firing PRB or lignite. Fuel moisture content affects performance, operation and emissions. Switching to a less expensive, lower rank (e.g. higher moisture or ash content) coal can increase the actual cost of generation through higher fuel input requirements, increased operations and maintenance costs, or lost generation capability due to equipment derates, increased auxiliary power consumption, or reduced unit availability.			
Industry Experience	The industry continues to show interest in fuel drying technology application. There are proprietary technologies that are under development and are currently being tested that utilize waste heat. Utilities and equipment suppliers are participating in demonstration projects to determine the viability of the technology.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Heat rate improvements will vary depending on the fuel type and the boiler technology. A private power plant operator of a lignite power plant with two 546 MW boilers conducted a test to document the benefits of fuel drying. The findings were that the boiler efficiency and net unit heat rate each improved 0.5 percent. Other tests found that the heat rate decreased 2.8% as a result of drier fuel. Boiler efficiency improves because there is less moisture to evaporate in the boiler therefore more heat is transferred to the steam.	1.00%	2.50%	3.50%
Aux Power Reduction	Further analysis of the findings from various coal drying reports noted the coal mills power consumption was reduced by approximately 17 percent and the fan power was reduced by 3.8 percent. The average total aux power reduction was 3.8 percent of the fan's aux power consumption. Assuming that there were five pulverizers rated at 600 HP, two PA fans rated at 1578 HP, two FD fans rated at 1160 HP and two ID fans rated at 5296 HP, the total fan aux power consumption would total 9,587 kW assuming an 80% capacity factor and the five pulverizers would have a load of 1789 kW. The aux reduction under this case would result in 668 kW savings.	0.010	0.038	0.043
Capacity	No change in capacity is expected. However the fuel drying potentially would enable the unit to regain lost capacity if derated due to firing lower quality fuels.	0.00%	0.00%	0.00%
Costs				
Capital Investment	The capital cost for an example project was announced in July 2007 at an estimated cost of \$20,000,000. That coal drier project is located adjacent to the mining operation and utilizes waste heat from the power station. For another project using a blend of PRB and bituminous coal, the capital cost was estimated at \$17,000,000 (in 2006 dollars). The cost difference is a function of drier technologies, waste heat source, plant or mine location and cost of steel, other construction materials, piping, and order lead time.	\$20,000,000	\$25,000,000	\$35,000,000
Operating Costs	Auxiliary power requirements for the pulverizer, PA fans, ID fans, and FGD system are expected to decrease. Depending on current unit configuration, a marginal net increase or decrease could be seen.	\$0	\$0	\$0
Maintenance Costs	Drier coal is easier to convey, flows better, and results in less maintenance for the initial plant systems. However, because this is a new coal handling and transport process there will be incremental maintenance expense to maintain it.	\$50,000	\$100,000	\$125,000
Availability and Reliability Issues				
Availability	No change in availability is expected.	0.00%	0.00%	0.00%
Reliability	The unit reliability may improve slightly as a result of the utilization of the improved fuel. The dried fuel will result in less fuel throughput and can lead to reduced issues of fouling and slagging of the boiler and furnace.	0.05%	0.20%	0.30%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 1 of 2)			
Major Equipment:	Fans			
Project Title:	FD Fan VFD Application			
Project Description				
Purpose	This project involves replacing the existing single constant speed induction or synchronous motors with a variable frequency drive (VFD) on the FD fans. The benefits of VFD are energy savings from lower aux power consumption and lower in rush current when starting the motor.			
Project Description	The project begins with a comparative analysis of various options of operating constant speed FD fans with excess capacity and use dampers to control and restrict flow. VFD controls the induction or synchronous speed by varying from maximum rated speed to very low speeds by reducing the frequency and line voltage imposed on the motor terminals. If the currently installed motor is oversized the VFD allows the motor to operate at lower RPMs and still meet the air flow requirements. Additionally there is no need for dampers to restrict air flow when the unit is operating at lower loads, where a single constant speed motor would require dampers to control the air flow at lower loads which consumes more power. The project requires a four to six week outage and adequate lead time for delivery of VFD controls and equipment. The VFD components are installed in self-contained enclosures suitable for outdoor ambient conditions.			
Qualifications	This project is generally feasible when the existing FD fan motors are designed with excess capacity, the unit mode of operation is load following, and axial fans with variable pitch blades are not in use. If the FD fans are axial fans with variable pitch fan blades the potential savings in aux power consumption will be smaller. Units that operate in a load following mode vary load throughout the day and can benefit with VFD when at part loads.			
Industry Experience	Applications of VFDs have been used by utilities for boiler draft applications since the late 1970s with reliable operating performance and have become an accepted standard for high efficiency fan controls.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Incremental heat rate improvements will be achieved from reduced aux power consumption.	0.00%	0.00%	0.00%
Aux Power Reduction	Benefit of VFD applications for FD fans is based on several key factors. These include excess capacity of existing motor, fan design and load profiles, coupling type, use of dampers and duct systems. The motor excess capacity was one of the biggest factors. In most cases, the VFD provided the highest reduction in aux power consumption when the unit is operating between 50 and 70 percent of MCR. The actual reduction in aux power is directly related to the unit annual hours of operation and percentage of time the unit operates at MCR versus reduced load. When comparing the power consumption of a single speed motor to one controlled by a VFD, the power savings when the unit operated at less than full load was significant. For this analysis a conservative estimate of a 5% reduction in fan power requirements was used.	0.50	0.85	1.00
Capacity	No capacity increases are generated from this project. The benefit is a reduction in aux power consumption.	0.00%	0.00%	0.00%

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 2 of 2)			
Major Equipment:	Fans			
Project Title:	FD Fan VFD Application			
Costs				
Capital Investment	Capital costs are derived for actual vendors' quotes and the final costs are based on construction and installation quotes. Additional comparative costs look at annual fixed charge rates, energy costs, and demand costs. When comparing a VFD to a single constant speed motor driven fan, the constant speed motor will have a higher energy costs and demand costs because this is energy and capacity (demand) than can be sold on the market instead of being consumed as part of the plant's aux power usage. In this project, the capital cost is the installed cost for two VFDs. The ranges of cost are based on VFD equipment, configuration and location where the drives will be installed, cabling, power center location, power conditioning equipment, foundation requirements, delivery time, and size of motor that is being coupled to the VFD.	\$600,000	\$1,600,000	\$3,000,000
Operating Costs	VFDs require heat rejection and if smaller than 4400 HP are generally cooled by an air source. Equipment larger than 4400 HP requires a water cooling heat rejection source. VFD must operate in a controlled environment that is air conditioned and dust free and comply with NEMA 1 guidelines. However, parasitic power use for the VFD is more than offset by the aux power reduction of the fan.	\$0	\$500	\$2,000
Maintenance Costs	Annual maintenance costs include monthly or quarterly testing of controls, replacement of seals, packing, filters, and OEM service contracts. This is the basis for a range of cost depending on required maintenance and nature of the negotiated service contract. Mechanical inspection checks should include internal VFD components such as check circulating fans for signs of bearing failure or foreign objects. Costs include 1/2 FTE at a cost of 100,000 per year to maintain the VFD system and controls plus a small amount of materials.	\$1,500	\$2,500	\$3,500
Availability and Reliability Issues				
Availability	The availability of the unit should generally be unchanged as the VFD systems do not require additional outage time as compared to major fans with single constant speed drive motors.	0.00%	0.00%	0.00%
Reliability	The reliability of the unit is not expected to change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 1 of 2)			
Major Equipment:	Fans			
Project Title:	PA Fan VFD Application			
Project Description				
Purpose	This project involves replacing the existing single constant speed induction or synchronous motors with a variable frequency drive (VFD) on the PA fans. The benefits of VFD are energy savings from lower aux power consumption and lower in rush current when starting the motor.			
Project Description	The project begins with a comparative analysis of various options of operating constant speed PA fans with excess capacity and use dampers to control and restrict flow. VFD controls the induction or synchronous speed by varying from maximum rated speed to very low speeds by reducing the frequency and line voltage imposed on the motor terminals. If the currently installed motor is oversized the VFD allows the motor to operate at lower RPMs and still meet the air flow requirements. Additionally there is no need for dampers to restrict air flow when the unit is operating at lower loads, where a single constant speed motor would require dampers to control the air flow at lower loads which consumes more power. The project requires a four to six week outage and adequate lead time for delivery of VFD controls and equipment. The VFD components are installed in self-contained enclosures suitable for outdoor ambient conditions.			
Qualifications	This project is generally feasible when the existing PA fan motors are designed with excess capacity and the unit mode of operation is load following with a substantial portion of the time at reduced load. Units that operate in a load following mode vary load throughout the day and can benefit with VFD when at part loads.			
Industry Experience	Applications of VFDs have been used by utilities for boiler draft applications since the late 1970s with reliable operating performance and have become an accepted standard for high efficiency fan controls.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Incremental heat rate improvements will be achieved from reduced aux power consumption.	0.00%	0.00%	0.00%
Aux Power Reduction	Benefit of VFD applications for PA fans is based on several key factors. These include excess capacity of existing motor, fan design and load profiles, coupling type, use of dampers and duct systems. The motor excess capacity was one of the biggest factors. In most cases, the VFD provided the highest reduction in aux power consumption when the unit is operating between 50 and 70 percent of MCR. The actual reduction in aux power is directly related to the unit annual hours of operation and percentage of time the unit operates at MCR versus reduced load. When comparing the power consumption of a single speed motor to one controlled by a VFD, the power savings when the unit operated at less than full load was significant. For this analysis a conservative estimate of a 6% reduction in fan power requirements was used.	0.132	0.396	0.528
Capacity	No capacity increases are generated from this project. The benefit is a reduction in aux power consumption.	0.00%	0.00%	0.00%

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 2 of 2)			
Major Equipment:	Fans			
Project Title:	PA Fan VFD Application			
Costs				
Capital Investment	Capital costs are derived for actual vendors' quotes and the final costs are based on construction and installation quotes. Additional comparative costs look at annual fixed charge rates, energy costs, and demand costs. When comparing a VFD to a single constant speed motor driven fan, the constant speed motor will have a higher energy costs and demand costs because this is energy and capacity (demand) than can be sold on the market instead of being consumed as part of the plant's aux power usage. In this project, the capital cost is the installed cost for two VFDs. The ranges of cost are based on VFD equipment, configuration and location where the drives will be installed, cabling, power center location, power conditioning equipment, foundation requirements, delivery time, and size of motor that is being coupled to the VFD.	\$600,000	\$1,200,000	\$3,000,000
Operating Costs	VFDs require heat rejection and if smaller than 4400 HP are generally cooled by an air source. Equipment larger than 4400 HP requires a water cooling heat rejection source. VFD must operate in a controlled environment that is air conditioned and dust free and comply with NEMA 1 guidelines. However, parasitic power use for the VFD is more than offset by the aux power reduction of the fan.	\$0	\$500	\$2,000
Maintenance Costs	Annual maintenance costs include monthly or quarterly testing of controls, replacement of seals, packing, filters, and OEM service contracts. This is the basis for a range of cost depending on required maintenance and nature of the negotiated service contract. Mechanical inspection checks should include internal VFD components such as check circulating fans for signs of bearing failure or foreign objects. Costs include 1/2 FTE at a cost of 100,000 per year to maintain the VFD system and controls plus a small amount of materials.	\$1,500	\$2,500	\$3,500
Availability and Reliability Issues				
Availability	The availability of the unit should generally be unchanged as the VFD systems do not require additional outage time as compared to major fans with single constant speed drive motors.	0.00%	0.00%	0.00%
Reliability	The reliability of the unit is not expected to change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 1 of 2)			
Major Equipment:	Fans			
Project Title:	ID Fan VFD Application			
Project Description				
Purpose	This project involves replacing the existing single constant speed induction or synchronous motors with a variable frequency drive (VFD) on the ID fans. The benefits of VFD are energy savings from lower aux power consumption and lower in rush current when starting the motor.			
Project Description	The project begins with a comparative analysis of various options of operating constant speed ID fans with excess capacity and use dampers to control and restrict flow. VFD controls the induction or synchronous speed by varying from maximum rated speed to very low speeds by reducing the frequency and line voltage imposed on the motor terminals. If the currently installed motor is oversized the VFD allows the motor to operate at lower RPMs and still meet the air flow requirements. Additionally there is no need for dampers to restrict air flow when the unit is operating at lower loads, where a single constant speed motor would require dampers to control the air flow at lower loads which consumes more power. The project requires a four to six week outage and adequate lead time for delivery of VFD controls and equipment. The VFD components are installed in self-contained enclosures suitable for outdoor ambient conditions.			
Qualifications	This project is generally feasible when the existing ID fan motors are designed with excess capacity, the unit mode of operation is load following, and axial fans with variable pitch blades are not in use. If the ID fans are axial fans with variable pitch fan blades the potential savings in aux power consumption will be smaller. Units that operate in a load following mode vary load throughout the day and can benefit with VFD when at part loads.			
Industry Experience	Applications of VFDs have been used by utilities for boiler draft applications since the late 1970s with reliable operating performance and have become an accepted standard for high efficiency fan controls.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Incremental heat rate improvements will be achieved from reduced aux power consumption.	0.00%	0.00%	0.00%
Aux Power Reduction	Benefit of VFD applications for ID fans is based on several key factors. These include excess capacity of existing motor, fan design and load profiles, coupling type, use of dampers and duct systems. The motor excess capacity was one of the biggest factors. In most cases, the VFD provided the highest reduction in aux power consumption when the unit is operating between 50 and 70 percent of MCR. The actual reduction in aux power is directly related to the unit annual hours of operation and percentage of time the unit operates at MCR versus reduced load. When comparing the power consumption of a single speed motor to one controlled by a VFD, the power savings when the unit operated at less than full load was significant. For this analysis a conservative estimate of a 8% reduction in fan power requirements was used.	0.24	0.48	0.68
Capacity	No capacity increases are generated from this project. The benefit is a reduction in aux power consumption.	-0.10%	0.00%	0.10%

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units (Page 2 of 2)			
Major Equipment:	Fans			
Project Title:	ID Fan VFD Application			
Costs				
Capital Investment	Capital costs are derived for actual vendors' quotes and the final costs are based on construction and installation quotes. Additional comparative costs look at annual fixed charge rates, energy costs, and demand costs. When comparing a VFD to a single constant speed motor driven fan, the constant speed motor will have a higher energy costs and demand costs because this is energy and capacity (demand) than can be sold on the market instead of being consumed as part of the plant's aux power usage. In this project, the capital cost is the installed cost for two VFDs. The ranges of cost are based on VFD equipment, configuration and location where the drives will be installed, cabling, power center location, power conditioning equipment, foundation requirements, delivery time, and size of motor that is being coupled to the VFD.	\$1,750,000	\$2,260,000	\$2,800,000
Operating Costs	VFDs require heat rejection and if smaller than 4400 HP are generally cooled by an air source. Equipment larger than 4400 HP requires a water cooling heat rejection source. VFD must operate in a controlled environment that is air conditioned and dust free and comply with NEMA 1 guidelines. However, parasitic power use for the VFD is more than offset by the aux power reduction of the fan.	\$0	\$500	\$2,000
Maintenance Costs	Annual maintenance costs include monthly or quarterly testing of controls, replacement of seals, packing, filters, and OEM service contracts. This is the basis for a range of cost depending on required maintenance and nature of the negotiated service contract. Mechanical inspection checks should include internal VFD components such as check circulating fans for signs of bearing failure or foreign objects. Costs include 1/2 FTE at a cost of 100,000 per year to maintain the VFD system and controls plus a small amount of materials.	\$1,500	\$2,500	\$3,500
Availability and Reliability Issues				
Availability	The availability of the unit should generally be unchanged as the VFD systems do not require additional outage time as compared to major fans with single constant speed drive motors.	0.00%	0.00%	0.00%
Reliability	The reliability of the unit is not expected to change.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Fans			
Project Title:	Air Heater Seals			
Project Description				
Purpose	This project involves upgrading the air preheater seals by employing a design to reduce air leakage that negatively affects the unit's performance.			
Project Description	Replacing leaking radial rotary air heater seals is one way to enhance the performance of the air heater. If the air heater experiences excessive seal leakage, the FD and ID fans move more air / gas and consume more aux power. Both third party vendors and OEMs manufacture custom seals that are more flexible and provide a tighter fit. This capital project would completely replace the original seals with one that would reduce the air in leakage to a range of 10% or less. Seals are typically planned for replacement every 3 years and as such, leakage reduction past that point cannot be considered to be reliable.			
Qualifications	Complete replacement of air preheater seals is applicable for all coal fired boilers with rotating APH regardless of fuel type. Boilers burning PRB coal can benefit by maintaining a high mill inlet air temperature that will drive out the additional moisture inherent in PRB coals.			
Industry Experience	Upgrading the air preheater seals and benefits derived are well documented. OEM suppliers and third party vendors have identified several utilities that have benefited from total replacement of special configured flexible seals. Replacing seals during a major planned boiler outage is a common practice which occurs about every three to five years depending on the amount of wear or other damage.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	Heat rate improvements will vary with unit size and boiler configuration. The improvement will vary with air heater configuration (bi-sector, tri sector), unit size and the condition of the current seals.	0.10%	0.50%	1.00%
Aux Power Reduction	Replacing leaking radial rotary air heater seals is one way to enhance the performance of the air heater. If the air heater experiences excessive seal leakage, the FD and ID fans move more air / gas and consume more aux power. Studies have found air in leakage on 500 MW units can be as high as 30 percent depending on seal technology. For the example case it is assumed the current state of air in leakage can be reduced 10%. Reference studies on ID fan performance corroborate a similar magnitude reduction. The result was a reduction of 0.165 MW in aux power consumption the first year.	0.075	0.110	0.165
Capacity	No increase in capacity is expected.	0.00%	0.00%	0.00%
Costs				
Capital Investment	The estimated cost for a 500 MW unit seal replacement is approximately \$185,000. Unique custom designed seals with special metals will increase the capital cost.	\$150,000	\$185,000	\$200,000
Operating Costs	No change in operating costs are expected.	\$0	\$0	\$0
Maintenance Costs	No change in maintenance costs are expected.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No change in availability is expected.	0.00%	0.00%	0.00%
Reliability	No change in reliability is expected.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. To estimate the real benefits of this project, air heater leakage need to be performed on all units. The potential benefit will depend on the extent of air heater leakage and will be air heater specific.				

Note: The replacement of existing air heater seals with improved seals was deemed unfeasible at Ameren due to the relatively short service life of the new seals. None of the vendors contacted had an improved replacement seal with an expected life long enough to meet the projected length between major outages at Ameren.

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Fans			
Project Title:	Air Heater Baskets			
Project Description				
Purpose	This project is undertaken to improve the efficiency of the plant by upgrading the air preheater basket capacity with the goal of maintaining the designed air outlet temperature.			
Project Description	This project involves replacing the air heater baskets. Air heater baskets are subject to pluggage and corrosion from ash in the flue gas. New baskets are available with specially designed thermal profiles and configurations that offer better performance. Air heater basket replacement requires a four to six week planned outage.			
Qualifications	There are multiple reasons for replacing the air heater baskets. Most commonly, basket replacement is justified by corrosion and/or pluggage. Additions such as a SCR and fuel changes can also affect the air heater and drive the need for modifications.			
Industry Experience	Air heater basket replacement is a common practice in the industry with multiple OEM and third party vendors and contractors offering solutions. Utilities have replaced the air heater baskets for multiple reasons including poor performance as well as issues related to blockage and damage resulting from corrosion.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	At present replacement of seals and new baskets has the potential to reduce leakage by as much as 50% of current leakage, with a leakage floor of 10-12%. However, this reduction is also a function of seal life and related wear. The resulting reduction wanes over time from 50% initially to 10% after 3 years.	0.50%	1.00%	2.00%
Aux Power Reduction	Reduced power consumption from reduced fan loading to overcome smaller pressure drops will be one outcome from basket elements with new configuration designed to eliminate pluggage.	0.125	0.165	0.220
Capacity	The air heater will be able to provide hotter combustion air to the coal mills and burner and increase the combustion efficiency.	0.50%	1.00%	2.00%
Costs				
Capital Investment	The capital cost of air heater basket replacement is based on an estimate to replace the existing baskets of a 500 MW coal fired unit with ceramic type baskets. The cost includes removal of the existing baskets, replacement of seals, new baskets and installation. The variance in capital cost is a function of unit size, the number of layers of baskets, choice of replacing existing baskets with OEM original design, basket materials, and thermodynamic properties of the baskets. The cost is also impacted by plant site constraints and access to the construction and air heater area.	\$1,000,000	\$1,700,000	\$2,000,000
Operating Costs	No incremental costs are expected.	\$0	\$0	\$0
Maintenance Costs	No incremental maintenance costs are expected.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	No effect on availability in anticipated.	0.00%	0.00%	0.00%
Reliability	Reliability could improve by reducing or eliminating outages associated with plugging and possible damage associated with severe corrosion. This potential would be greatest in units that have already experienced significant corrosion and loss of material.	0.00%	0.05%	1.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity																																													
Unit	All Applicable Units																																												
Major Equipment:	Balance of Plant																																												
Project Title:	Station Air System																																												
Project Description																																													
Purpose	The purpose of this project is to contribute to the incremental reduction in the auxiliary consumption of energy used by the plant's compressed air system. Capital investment targets upgrading the compressor and air dryers to prime movers with variable frequency drives and premium efficiency motors.																																												
Project Description	Air compressors increasingly are adopting the use of high efficiency motors and variable frequency drives (VFD). For power plant operators looking at ways to reduce the consumption of auxiliary energy, replacing their plant's existing compressed air system might be one measure worth undertaking. Older compressors installed more than 20 years ago tended to be reciprocating compressor systems that operated at efficiency levels of 80%. Modern compressor systems operate with efficiencies in the 90% or better range.																																												
Qualifications	Replacing the existing compressed air system should be governed by the equipment service duty, type of compressor, number of stages, and the amount of time the unit operates at full load. Compressed air systems installed before 1988 are candidates for replacements. Compressed air systems installed before 1997 should be inspected to identify efficiency levels of the motors and potential applications for variable frequency drives (VFDs). VFD is more applicable for units that cycle frequently. If the compressor runs fully loaded most of the time, VFDs could result in a small penalty in the range of 1 to 4 percent. Otherwise, the savings could be significant in the range of 10 to 25 percent.																																												
Industry Experience	Compressed air system are vital equipment in power plants. Advancements have been made in centrifugal and screw compressors. Compressed air systems are historically known to be some of the largest consumers of energy at any industrial site. The Iowa Department of Natural Resources conducted compressed air system audits over the past 10 years and summary statistics indicate the nominal leakage rate identified within the manufacturing industry near 30%. This figure is corroborated by the U.S. Department of Energy.																																												
Example Project Valuation and Description of Uncertainties																																													
Benefits	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 60%;"></th> <th style="width: 16.6%;">Low</th> <th style="width: 16.6%;">Expected</th> <th style="width: 6.2%;">High</th> </tr> </thead> <tbody> <tr> <td>Heat Rate</td> <td style="text-align: center;">0.05%</td> <td style="text-align: center;">0.10%</td> <td style="text-align: center;">0.15%</td> </tr> <tr> <td>Aux Power Reduction</td> <td style="text-align: center;">0.0100</td> <td style="text-align: center;">0.0150</td> <td style="text-align: center;">0.0280</td> </tr> <tr> <td>Capacity</td> <td style="text-align: center;">0.00%</td> <td style="text-align: center;">0.00%</td> <td style="text-align: center;">0.00%</td> </tr> <tr> <td colspan="4">Costs</td> </tr> <tr> <td>Capital Investment</td> <td style="text-align: center;">\$125,000</td> <td style="text-align: center;">\$200,000</td> <td style="text-align: center;">\$275,000</td> </tr> <tr> <td>Operating Costs</td> <td style="text-align: center;">\$0</td> <td style="text-align: center;">\$0</td> <td style="text-align: center;">\$0</td> </tr> <tr> <td>Maintenance Costs</td> <td style="text-align: center;">\$0</td> <td style="text-align: center;">\$0</td> <td style="text-align: center;">\$0</td> </tr> <tr> <td colspan="4">Availability and Reliability Issues</td> </tr> <tr> <td>Availability</td> <td style="text-align: center;">0.00%</td> <td style="text-align: center;">0.00%</td> <td style="text-align: center;">0.00%</td> </tr> <tr> <td>Reliability</td> <td style="text-align: center;">0.00%</td> <td style="text-align: center;">0.01%</td> <td style="text-align: center;">0.05%</td> </tr> </tbody> </table>		Low	Expected	High	Heat Rate	0.05%	0.10%	0.15%	Aux Power Reduction	0.0100	0.0150	0.0280	Capacity	0.00%	0.00%	0.00%	Costs				Capital Investment	\$125,000	\$200,000	\$275,000	Operating Costs	\$0	\$0	\$0	Maintenance Costs	\$0	\$0	\$0	Availability and Reliability Issues				Availability	0.00%	0.00%	0.00%	Reliability	0.00%	0.01%	0.05%
	Low	Expected	High																																										
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Source of Data	The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements. Note that cost is based on one compressor and redundant systems would be higher.																																												

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Boiler			
Project Title:	Blowdown Recovery Tank			
Project Description				
Purpose	The blowdown water has already been raised to drum pressure and temperature. The purpose of the blowdown recovery tank is to recover as much of the energy from the blowdown water as possible before it leaves the cycle.			
Project Description				
Qualifications	Rush Island currently has blowdown recovery tanks.			
Industry Experience				
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	The heat rate benefit was based on data from an e-mail obtained from Ameren's Research and Development department. The benefit would depend on the amount of blowdown flow on the units.		0.20%	
Aux Power Reduction	No change		0.0000	
Capacity	No change		0.00%	
Costs				
Capital Investment	The capital investment was based on data from an e-mail obtained from Ameren's Research and Development department.		\$3,000,000	
Operating Costs	The operating costs were based on data from an e-mail obtained from Ameren's Research and Development department.		\$50,000	
Maintenance Costs	The capital investment costs were based on data from an e-mail obtained from Ameren's Research and Development department.		\$50,000	
Availability and Reliability Issues				
Availability	No change		0.00%	
Reliability	No change		0.00%	
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity				
Unit	All Applicable Units			
Major Equipment:	Precipitators			
Project Title:	ESP Power Supply Upgrade			
Project Description				
Purpose	The purpose of this project is to improve the efficiency and performance of the ESP's and reduce the auxiliary power usage of the ESPs.			
Project Description	The project consists of replacing the existing 60 Hz power supplies with High Frequency Power Supply (HFPS). This would require that the unit be shut down because the ESP would need to be shut down. It would be recommended that this take place when the ESP is down for planned maintenance and needed repairs. Meramec is planned to have this done on several units in the near future 2013 and beyond.			
Qualifications	All units with ESP's. ESP needs to be in good condition and with good air distribution.			
Industry Experience	Southern Environmental was contacted for this option and they have installed over 300 of the HFPS to date. It has been installed in 2 units in the AEG territory.			
Example Project Valuation and Description of Uncertainties				
Benefits		Low	Expected	High
Heat Rate	No change in heat rate for this option.	0.00%	0.00%	0.00%
Aux Power Reduction	This is the main reason for AUE to upgrade to HFPS. A range of 15-30% reduction was given by the vendor. Normal use for current ESPs is about 500 kW.	0.0750	0.1000	0.1400
Capacity	No change in capacity.	0.00%	0.00%	0.00%
Costs				
Capital Investment	The capital investment is plant specific and depends on how many TR sets are at each facility. This information is based on unit which has 24 TR sets.	\$840,000	\$960,000	\$1,080,000
Operating Costs	There are no additional Operating costs.	\$0	\$0	\$0
Maintenance Costs	There are no additional maintenance costs.	\$0	\$0	\$0
Availability and Reliability Issues				
Availability	The equipment can be installed during a planned outage. Would be recommended to be done when the ESP is having repair or upgrade work done.	0.00%	0.00%	0.00%
Reliability	At present we have not had many issues with being derated due to excessive opacity. A big selling point for HFPS is that it makes the ESP more efficient and therefore plants that have been derated due to opacity would get an increase in reliability. However since AUE does not have these issues we would not get this benefit directly.	0.00%	0.00%	0.00%
Source of Data				
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.				

Ameren Missouri Heat Rate Improvement Project Opportunity Forms

Heat Rate Improvement Project Opportunity	
Unit	All Applicable Units
Major Equipment:	Circulating Water
Project Title:	Circulating Water Discharge Turbines
Project Description	
Purpose	The purpose of this project is to recover the potential energy from the circulating water as it flows from the condenser to the discharge canal.
Project Description	Install a small hydro plant on the circulating water discharge.
Qualifications	The Yeongheung Power Plant installed a small (3 MW) hydro plant on the Unit 3 & 4 circulating water discharge. The Yeongheung units are 870 MW each. The cost of the project was \$9.36MM and it produces 11,892 MWhr per year. They plan to install an additional 5 MW on Units 1&2.
Industry Experience	
Example Project Valuation and Description of Uncertainties	
Benefits	Low Expected High
Heat Rate	No change
Aux Power Reduction	No change.
Capacity	The capacity increase was based on a potential 1MW plant increase (or a 0.25 MW increase for a 630 MW unit) This corresponds to approximately 0.04% increase in capacity).
Costs	
Capital Investment	The expected cost were based on the Yeongheung Power Plant case described above (\$9,360,000 / 1740 MW or \$5,400 / MW Unit capacity).
Operating Costs	No change.
Maintenance Costs	Assumed to be 1% of capital cost.
Availability and Reliability Issues	
Availability	No change.
Reliability	No change.
Source of Data	
The above cells highlighted in green originate from EPRI Report 1015735, Capital Projects for Efficiency Improvements.	

B

AMEREN MISSOURI PEET ANALYSIS—PROJECT RANKING LIST

Ameren Missouri PEET Analysis—Project Ranking List

Project #	Component	Unit	Net Annual Cost (including effective heat rate improvement) per ton of CO2 avoided (using total CO2 Emission Benefits) (\$/ton of CO2)	Total CO2 Emissions Avoided (tons)	Cumulative CO2 Emissions Avoided (tons)	Est Capital Cost (Scaled to Unit size) (\$000)	Cumulative Capital Cost (\$000)
1	Automate Boiler Drains	J	-\$19.85	6370.1	6370.1	\$72	\$72
2	Automate Boiler Drains	I	-\$19.79	6031.5	12401.6	\$72	\$144
3	Automate Boiler Drains	L	-\$17.22	8545.9	20947.5	\$79	\$223
4	Automate Boiler Drains	K	-\$17.10	8051.2	28998.6	\$80	\$303
5	Automate Boiler Drains	F	-\$16.78	8472.1	37470.8	\$79	\$382
6	Air Heater Seals	L	-\$16.71	22159.9	59630.7	\$211	\$594
7	Automate Boiler Drains	G	-\$16.71	8322.1	67952.8	\$80	\$674
8	Automate Boiler Drains	H	-\$16.71	8518.2	76471.0	\$80	\$754
9	Automate Boiler Drains	E	-\$16.70	8135.1	84606.1	\$80	\$834
10	Automate Boiler Drains	D	-\$16.68	4415.4	89021.5	\$67	\$901
11	Air Heater Seals	K	-\$16.59	20856.2	109877.7	\$213	\$1,114
12	Automate Boiler Drains	C	-\$16.48	3854.8	113732.6	\$61	\$1,175
13	Air Heater Seals	H	-\$16.20	22072.5	135805.1	\$213	\$1,388
14	Air Heater Seals	G	-\$16.18	21563.1	157368.2	\$213	\$1,601
15	Air Heater Seals	F	-\$16.18	21966.1	179334.2	\$212	\$1,812
16	Air Heater Seals	E	-\$16.11	21066.5	200400.8	\$214	\$2,027
17	Automate Boiler Drains	A	-\$15.85	1828.9	202229.6	\$47	\$2,074
18	Air Heater Seals	C	-\$15.76	10440.2	212669.8	\$162	\$2,236
19	Air Heater Seals	D	-\$15.76	11728.4	224398.2	\$178	\$2,413
20	Automate Boiler Drains	B	-\$15.71	1781.9	226180.1	\$47	\$2,460
21	Air Heater Baskets	L	-\$11.86	43922.2	270102.3	\$2,115	\$4,575
22	Air Heater Baskets	F	-\$11.37	43539.2	313641.6	\$2,117	\$6,692
23	Station Air System	J	-\$10.49	3293.6	316935.2	\$264	\$6,956
24	Station Air System	I	-\$10.11	3118.6	320053.8	\$264	\$7,219
25	Circulating Water Strainers	J	-\$9.21	30402.7	350456.5	\$2,396	\$9,615
26	Circulating Water Strainers	L	-\$8.61	41283.3	391739.8	\$2,643	\$12,258
27	Circulating Water Strainers	I	-\$8.58	28786.9	420526.6	\$2,396	\$14,654
28	Circulating Water Strainers	H	-\$8.11	41178.5	461705.2	\$2,661	\$17,315
29	Air Heater Baskets	D	-\$8.07	23111.8	484816.9	\$1,779	\$19,094
30	Circulating Water Strainers	F	-\$8.07	40931.9	525748.8	\$2,646	\$21,740
31	Circulating Water Strainers	K	-\$7.96	38931.6	564680.4	\$2,668	\$24,409
32	Circulating Water Strainers	G	-\$7.84	40232.7	604913.1	\$2,663	\$27,071
33	Air Heater Baskets	C	-\$7.78	20478.8	625391.9	\$1,616	\$28,688
34	Condenser Ball Cleaning System	J	-\$7.68	6297.7	631689.6	\$623	\$29,311
35	Circulating Water Strainers	E	-\$7.59	39350.7	671040.3	\$2,677	\$31,988
36	Condenser Ball Cleaning System	L	-\$7.21	8473.6	679513.8	\$687	\$32,675
37	Condenser Ball Cleaning System	I	-\$6.93	5963.0	685476.8	\$623	\$33,298
38	Condenser Ball Cleaning System	F	-\$6.66	8400.7	693877.5	\$688	\$33,986
39	Condenser Ball Cleaning System	H	-\$6.59	8447.6	702325.1	\$692	\$34,678
40	Condenser Ball Cleaning System	K	-\$6.36	7984.9	710310.1	\$694	\$35,372
41	Condenser Ball Cleaning System	G	-\$6.34	8253.2	718563.3	\$692	\$36,064
42	Condenser Ball Cleaning System	E	-\$6.03	8068.9	726632.1	\$696	\$36,760
43	Water Cannons	D	-\$5.62	23958.5	750590.6	\$2,195	\$38,955
44	Exhaust Hood Steam Guide	J	-\$5.60	15925.2	766515.9	\$1,917	\$40,872
45	Exhaust Hood Steam Guide	L	-\$5.58	21364.6	787880.5	\$2,115	\$42,986
46	Exhaust Hood Steam Guide	H	-\$4.98	21295.6	809176.1	\$2,129	\$45,115
47	Exhaust Hood Steam Guide	F	-\$4.96	21180.3	830356.4	\$2,117	\$47,232
48	Exhaust Hood Steam Guide	I	-\$4.79	15078.8	845435.2	\$1,917	\$49,149
49	Exhaust Hood Steam Guide	K	-\$4.71	20127.9	865563.1	\$2,135	\$51,283
50	Exhaust Hood Steam Guide	F	-\$4.67	20805.3	886368.3	\$2,130	\$53,413
51	Plant Lighting	J	-\$4.36	2171.6	888540.0	\$287	\$53,701
52	Exhaust Hood Steam Guide	E	-\$4.29	20337.8	908877.8	\$2,142	\$55,843
53	Plant Lighting	I	-\$3.14	2056.2	910934.0	\$287	\$56,130
54	Circulating Water Strainers	D	-\$2.26	20822.6	931756.5	\$2,224	\$58,354
55	Plant Lighting	A	-\$1.81	1474.9	933231.4	\$188	\$58,543
56	Circulating Water Strainers	C	-\$1.22	17814.0	951045.4	\$2,021	\$60,563
57	Plant Lighting	B	-\$1.12	1425.6	952471.0	\$189	\$60,752
58	Condenser Ball Cleaning System	D	-\$0.24	4352.7	956823.7	\$578	\$61,330
59	Plant Lighting	L	\$0.31	2169.0	958992.7	\$317	\$61,648
60	Condenser Ball Cleaning System	C	\$0.67	3781.8	962774.5	\$525	\$62,173
61	Plant Lighting	F	\$0.80	2143.0	964917.5	\$318	\$62,491

Ameren Missouri PEET Analysis—Project Ranking List

Project #	Component	Unit	Net Annual Cost (including effective heat rate improvement) per ton of CO2 avoided (using total CO2 Emission Benefits) (\$/ton of CO2)	Total CO2 Emissions Avoided (tons)	Cumulative CO2 Emissions Avoided (tons)	Est Capital Cost (Scaled to Unit size) (\$000)	Cumulative Capital Cost (\$000)
62	Plant Lighting	H	\$1.38	2119.0	967036.5	\$319	\$62,810
63	Plant Lighting	G	\$1.94	2066.7	969103.2	\$320	\$63,129
64	Plant Lighting	K	\$2.11	1986.3	971089.5	\$320	\$63,450
65	Water Cannons	C	\$2.13	21464.4	992554.0	\$3,293	\$66,743
66	Economizer Retrofit	C	\$2.40	19274.2	1011828.2	\$3,233	\$69,976
67	Exhaust Hood Steam Guide	D	\$2.41	11038.5	1022866.6	\$1,779	\$71,755
68	Plant Lighting	E	\$2.67	1987.4	1024854.0	\$321	\$72,076
69	Plant Lighting	C	\$2.77	1460.2	1026314.2	\$242	\$72,319
70	Exhaust Hood Steam Guide	C	\$3.19	9637.1	1035951.3	\$1,616	\$73,935
71	H2 Purity	F	\$4.64	4150.3	1040101.6	\$635	\$74,570
72	H2 Purity	H	\$4.71	4174.4	1044276.0	\$639	\$75,209
73	H2 Purity	G	\$5.12	4078.4	1048354.4	\$639	\$75,848
74	H2 Purity	E	\$5.88	3988.1	1052342.4	\$643	\$76,490
75	H2 Purity	J	\$6.02	3098.2	1055440.6	\$575	\$77,065
76	H2 Purity	I	\$7.73	2933.5	1058374.1	\$575	\$77,640
77	Plant Lighting	D	\$8.92	1254.4	1059628.5	\$267	\$77,907
78	Circulating Water Strainers	A	\$11.98	7669.5	1067298.0	\$1,571	\$79,478
79	Circulating Water Strainers	B	\$12.76	7484.2	1074782.2	\$1,575	\$81,053
80	Condenser Ball Cleaning System	A	\$12.87	1755.1	1076537.3	\$408	\$81,461
81	Condenser Ball Cleaning System	B	\$13.87	1710.7	1078248.0	\$409	\$81,871
82	Economizer Retrofit	B	\$16.13	8909.7	1087157.7	\$2,520	\$84,390
83	Exhaust Hood Steam Guide	A	\$16.56	4572.2	1091729.9	\$1,257	\$85,647
84	Exhaust Hood Steam Guide	B	\$17.54	4454.9	1096184.7	\$1,260	\$86,907
85	H2 Purity	D	\$18.45	2132.4	1098317.2	\$534	\$87,441
86	FD Fan VFD	A	\$20.01	6288.3	1104585.5	\$1,885	\$89,325
87	H2 Purity	C	\$20.43	1839.8	1106425.3	\$485	\$89,810
88	FD Fan VFD	B	\$21.47	6058.6	1112483.9	\$1,890	\$91,700
89	ID Fan VFD	D	\$22.37	6271.9	1118755.8	\$2,000	\$93,700
90	LP Steam Path Upgrade	L	\$23.06	64093.9	1182849.7	\$21,116	\$114,816
91	LP Steam Path Upgrade	F	\$28.34	63540.9	1246390.6	\$23,394	\$138,210
92	LP Steam Path Upgrade	K	\$30.02	60383.7	1306774.3	\$23,283	\$161,493
93	FD Fan VFD	C	\$31.27	6205.7	1312980.0	\$2,425	\$163,918
94	IP Steam Seal Upgrade	D	\$32.53	2207.7	1315187.6	\$890	\$164,808
95	HP Steam Path Upgrade	C	\$34.20	19274.2	1334461.8	\$8,046	\$172,854
96	IP Steam Seal Upgrade	C	\$34.23	1927.4	1336389.2	\$808	\$173,662
97	FD Fan VFD	J	\$37.94	6152.9	1342542.2	\$2,875	\$176,537
98	FD Fan VFD	I	\$41.27	5825.9	1348368.1	\$2,875	\$179,412
99	Blowdown Recovery Tank	F	\$41.60	8472.1	1356840.2	\$3,176	\$182,587
100	Blowdown Recovery Tank	H	\$41.68	8518.2	1365358.4	\$3,193	\$185,780
101	Blowdown Recovery Tank	G	\$43.09	8322.1	1373680.5	\$3,195	\$188,975
102	LP Steam Path Upgrade	C	\$43.60	38548.4	1412228.9	\$19,000	\$207,975
103	ID Fan VFD	A	\$44.58	3539.8	1415768.7	\$1,759	\$209,735
104	LP Steam Seal Upgrade	C	\$44.64	1927.4	1417696.1	\$970	\$210,705
105	Blowdown Recovery Tank	E	\$44.81	8135.1	1425831.2	\$3,213	\$213,917
106	FD Fan VFD	D	\$45.03	5331.1	1431162.3	\$2,669	\$216,586
107	LP Steam Path Upgrade	A	\$45.89	19660.5	1450822.8	\$10,052	\$226,638
108	FD Fan VFD	L	\$46.74	6145.5	1456968.3	\$3,172	\$229,810
109	ID Fan VFD	B	\$46.88	3421.3	1460389.6	\$1,764	\$231,574
110	LP Steam Path Upgrade	B	\$47.74	19155.9	1479545.5	\$10,079	\$241,654
111	FD Fan VFD	F	\$48.04	6071.9	1485617.4	\$3,176	\$244,829
112	H2 Purity	A	\$48.13	825.9	1486443.4	\$377	\$245,206
113	FD Fan VFD	H	\$49.12	6003.7	1492447.1	\$3,193	\$248,399
114	H2 Purity	B	\$49.54	805.4	1493252.5	\$378	\$248,777
115	FD Fan VFD	G	\$50.94	5855.8	1499108.3	\$3,195	\$251,972
116	FD Fan VFD	K	\$53.39	5627.9	1504736.2	\$3,202	\$255,174
117	FD Fan VFD	E	\$54.11	5631.0	1510367.2	\$3,213	\$258,387
118	HP Steam Seal Upgrade	C	\$60.27	1927.4	1512294.6	\$1,212	\$259,599
119	ID Fan VFD	C	\$63.33	3504.4	1515799.0	\$2,263	\$261,862
120	IP Steam Seal Upgrade	A	\$68.20	914.4	1516713.4	\$628	\$262,491
121	IP Steam Seal Upgrade	B	\$70.23	891.0	1517604.4	\$630	\$263,121
122	IP Steam Path Upgrade	D	\$79.11	13246.2	1530850.5	\$10,322	\$273,443

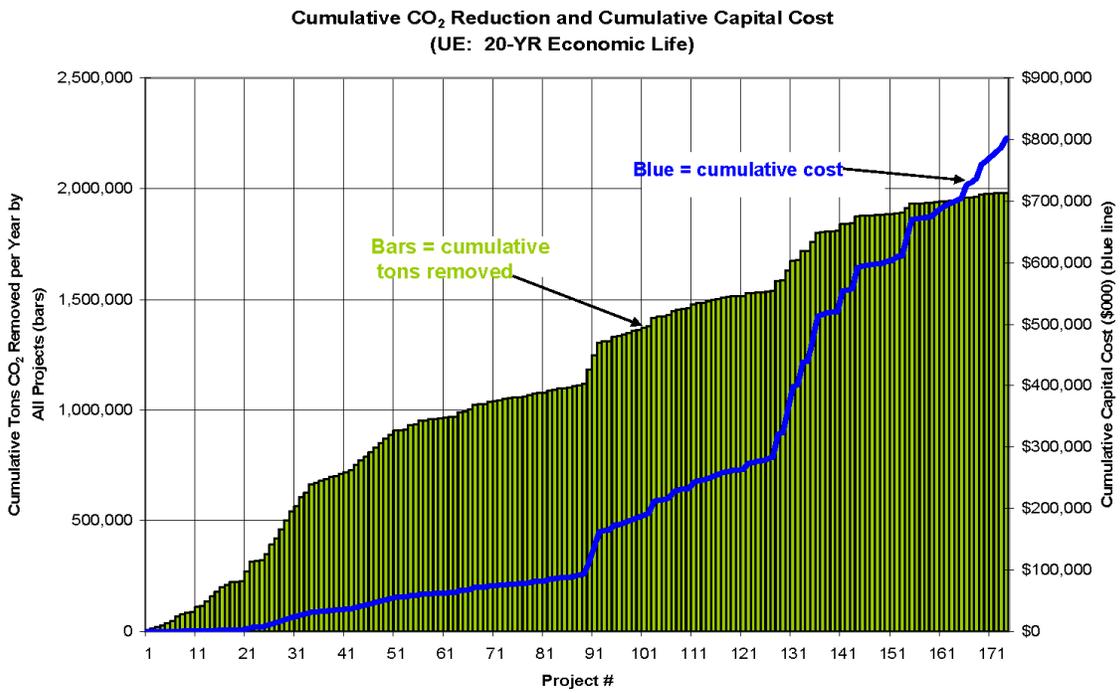
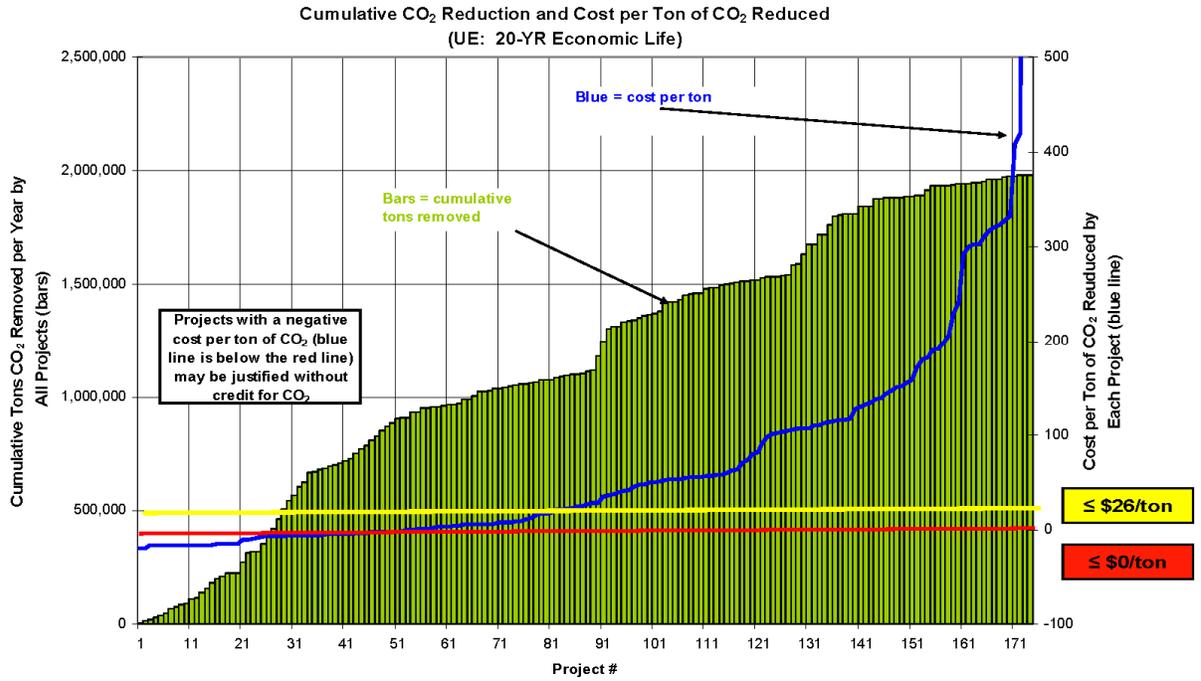
Ameren Missouri PEET Analysis—Project Ranking List

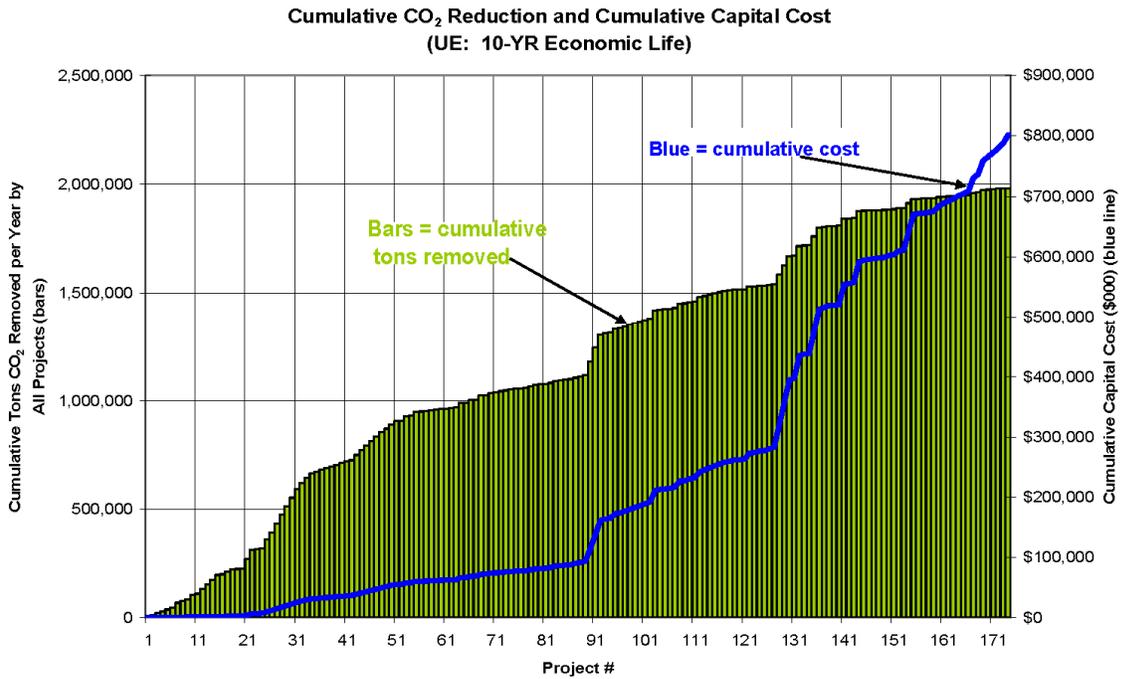
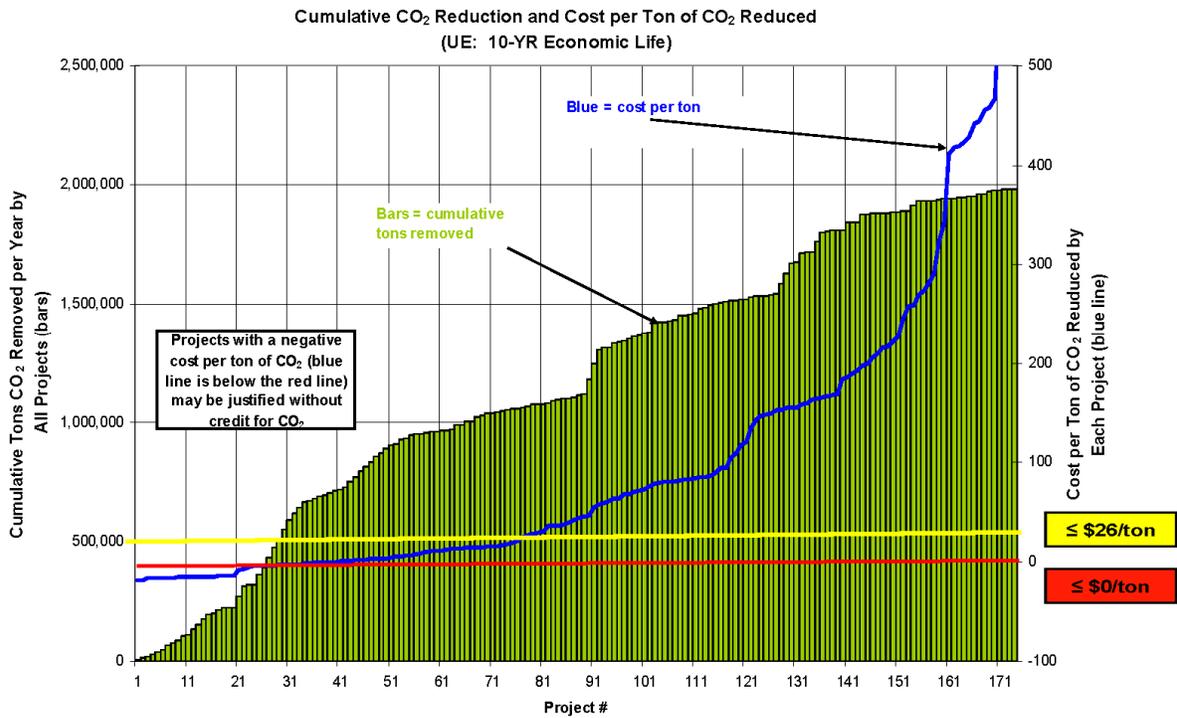
Project #	Component	Unit	Net Annual Cost (including effective heat rate improvement) per ton of CO2 avoided (using total CO2 Emission Benefits) (\$/ton of CO2)	Total CO2 Emissions Avoided (tons)	Cumulative CO2 Emissions Avoided (tons)	Est Capital Cost (Scaled to Unit size) (\$000)	Cumulative Capital Cost (\$000)
123	LP Steam Seal Upgrade	A	\$85.27	914.4	1531765.0	\$754	\$274,197
124	PA Fan VFD	C	\$87.32	2691.1	1534656.1	\$2,425	\$276,621
125	LP Steam Seal Upgrade	B	\$87.79	891.0	1535547.1	\$756	\$277,377
126	ID Fan VFD	L	\$89.07	3470.4	1539017.5	\$2,960	\$280,338
127	ID Fan VFD	F	\$90.86	3428.8	1542446.3	\$2,964	\$283,302
128	On-Site Fuel Drying	L	\$91.48	43004.0	1585450.3	\$37,006	\$320,306
129	ID Fan VFD	H	\$92.79	3390.3	1588840.7	\$2,980	\$323,288
130	On-Site Fuel Drying	F	\$93.01	42632.0	1631472.7	\$37,048	\$360,336
131	On-Site Fuel Drying	H	\$93.04	42659.6	1674332.3	\$37,255	\$397,591
132	ID Fan VFD	G	\$95.53	3306.8	1677639.1	\$2,982	\$400,573
133	On-Site Fuel Drying	G	\$95.73	41872.3	1719511.4	\$37,276	\$437,849
134	ESP Power Supplies	A	\$97.28	737.5	1720248.8	\$679	\$438,527
135	On-Site Fuel Drying	E	\$98.96	40927.3	1761176.2	\$37,480	\$476,007
136	On-Site Fuel Drying	K	\$99.33	40507.4	1801683.6	\$37,358	\$513,365
137	ID Fan VFD	K	\$100.02	3178.1	1804861.6	\$2,989	\$516,353
138	ID Fan VFD	E	\$100.65	3179.9	1808041.5	\$2,998	\$519,352
139	ESP Power Supplies	B	\$100.97	712.8	1808754.3	\$680	\$520,032
140	HP Steam Seal Upgrade	A	\$110.87	914.4	1809668.7	\$942	\$520,975
141	On-Site Fuel Drying	J	\$112.06	32125.5	1841794.2	\$33,540	\$554,515
142	HP Steam Seal Upgrade	B	\$114.14	891.0	1842685.2	\$945	\$555,459
143	PA Fan VFD	D	\$116.86	2483.7	1845168.9	\$2,669	\$558,128
144	On-Site Fuel Drying	I	\$119.54	30418.1	1875587.0	\$33,540	\$591,668
145	PA Fan VFD	L	\$120.80	2663.1	1878450.1	\$3,172	\$594,840
146	ESP Power Supplies	F	\$124.17	1000.1	1879450.2	\$1,143	\$595,983
147	ESP Power Supplies	H	\$127.39	988.8	1880439.0	\$1,150	\$597,133
148	ESP Power Supplies	G	\$130.72	964.5	1881403.5	\$1,150	\$598,283
149	ESP Power Supplies	C	\$131.33	730.1	1882133.6	\$873	\$599,156
150	PA Fan VFD	K	\$134.95	2621.9	1884755.5	\$3,202	\$602,358
151	ESP Power Supplies	E	\$137.90	927.5	1885682.9	\$1,157	\$603,515
152	IP Turbine Replacement	C	\$149.12	4818.5	1890501.5	\$6,466	\$609,981
153	ESP Power Supplies	J	\$156.77	723.9	1891225.4	\$1,035	\$611,016
154	On-Site Fuel Drying	D	\$159.62	22315.3	1913540.6	\$31,136	\$642,151
155	On-Site Fuel Drying	C	\$166.22	19551.6	1933092.2	\$28,289	\$670,440
156	ESP Power Supplies	I	\$167.03	685.4	1933777.6	\$1,035	\$671,475
157	ESP Power Supplies	D	\$171.96	627.2	1934404.8	\$961	\$672,436
158	ESP Power Supplies	L	\$178.77	723.0	1935127.8	\$1,142	\$673,578
159	ESP Power Supplies	K	\$198.83	662.1	1935789.9	\$1,153	\$674,730
160	LP Turbine Replacement	C	\$211.62	4818.5	1940608.5	\$8,891	\$683,621
161	IP Turbine Replacement	A	\$255.28	2286.1	1942894.6	\$5,026	\$688,647
162	IP Turbine Replacement	B	\$263.20	2227.4	1945122.0	\$5,040	\$693,687
163	Discharge Turbine	F	\$267.21	1694.4	1946816.4	\$3,601	\$697,288
164	Discharge Turbine	H	\$267.67	1703.6	1948520.1	\$3,621	\$700,909
165	Discharge Turbine	G	\$274.21	1664.4	1950184.5	\$3,623	\$704,532
166	On-Site Fuel Drying	A	\$278.85	9424.6	1959609.1	\$21,990	\$726,522
167	Discharge Turbine	E	\$283.15	1627.0	1961236.2	\$3,643	\$730,165
168	HP Turbine Replacement	A	\$283.21	2743.3	1963979.5	\$6,642	\$736,807
169	On-Site Fuel Drying	B	\$287.52	9180.6	1973160.1	\$22,049	\$758,856
170	HP Turbine Replacement	B	\$291.04	2672.9	1975833.0	\$6,642	\$765,498
171	LP Turbine Replacement	A	\$357.68	2286.1	1978119.1	\$6,911	\$772,409
172	LP Turbine Replacement	B	\$368.58	2227.4	1980346.5	\$6,930	\$779,338
173	Generator Rewind	J	\$1,509.21	637.0	1980983.5	\$8,000	\$787,338
174	Generator Rewind	C	\$4,610.97	385.5	1981369.0	\$14,500	\$801,838

Color Legend	\$/ton of CO2
Light Green	\$/ton of CO2 less than 0
Yellow	\$/ton of CO2 less than 26
Orange	\$/ton of CO2 less than 100
Dark Orange	\$/ton of CO2 greater than 100

C

AMEREN MISSOURI PEET SENSITIVITY ANALYSIS— VARIOUS ECONOMIC LIFE SCENARIOS





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