improves the NPHR by reducing both FD and ID fan flow requirements and can also benefit emissions control systems performance. Still another benefit would be the ability to better control the balance of O_2 across the furnace, which is known to be a current concern.

For A.B. Brown Unit 1, the excess oxygen varies roughly from between 2 percent to 4.5 percent at gross output levels above 250 MW, with an average level approximating 3.0 to 3.3 percent. No online correlation of NPHR or boiler efficiency from distributed control system (DCS) system calculations was readily available from which to draw a plant-specific correlation, but from examining the plant air heater temperature data, boiler temperature data, and other factors, it was estimated by utilizing representative plant models within the EPRI Vista fuel quality impact model that reducing the excess oxygen would result in the following improvements to boiler efficiency and heat rate:

- 0.25 percent reduction in excess O_2: 0.10 percent gain in boiler efficiency, 0.23 percent improvement in net plant heat rate.
- 0.50 percent reduction in excess O_2: 0.21 percent gain in boiler efficiency, 0.43 percent improvement in net plant heat rate.
- 0.75 percent reduction in excess O_2: 0.27 percent gain in boiler efficiency, 0.60 percent improvement in net plant heat rate.

Utilization of a specific Vista model of A.B. Brown Unit 1 would result in improved heat rate benefit estimates and should be considered as a next-phase effort. Hypothetically, it would be assumed that a modest reduction in boiler excess oxygen would be possible; therefore, if the unit could lower boiler outlet oxygen concentration by approximately 0.25 percent, then the NPHR improvement would be about 0.23 percent. The effects on NPHR were not linear because they varied as a function of auxiliary power changes, as well as changes in steam temperatures, which were affected by reduced excess O_2 levels.

Total Installed Capital Cost:	$500,000
Heat Rate (efficiency) Improvement:	0.23%

3.6.2 A.B. Brown Unit 2 Neural Network Deployment

The unit has the ability to bias individual mills as well as compartmented windboxes. Each burner row has an independent windbox with a damper for air control on each end, but there is only manual secondary air adjustment at each individual burner. There is no valid CO measurement [4]; thus, the unit must be restricted to an arbitrary O_2 lower limit to avoid typical low oxygen combustion issues such as slagging and tube wastage.

Reducing excess oxygen levels in the boiler increases the boiler efficiency by reducing sensible heat losses, although in some cases, unburned carbon losses can be increased (but almost never more than the sensible heat losses are reduced). In addition, reducing excess oxygen levels

[4] Lack of a valid CO measurement would significantly hamper the ability of a neural network system to affect positive change in unit operations.

improves the NPHR by reducing both FD and ID fan flow requirements and can also benefit emissions control systems performance.

For A.B. Brown Unit 2, the excess oxygen varies roughly from between 2 percent to 4.5 percent at gross output levels above 250 MW, with an average level approximating 3.1 to 3.3 percent. No online correlation of NPHR or boiler efficiency from DCS system calculations was readily available from which to draw a plant-specific correlation, but from examining the plant air heater temperature data, boiler temperature data, and other factors, it was estimated by utilizing representative plant models within the EPRI Vista fuel quality impact model that reducing the excess oxygen would result in the following improvements to boiler efficiency and heat rate (these are the same as A.B. Brown Unit 1):

- 0.25 percent reduction in excess O_2: 0.10 percent gain in boiler efficiency, 0.23 percent improvement in net plant heat rate.
- 0.50 percent reduction in excess O_2: 0.21 percent gain in boiler efficiency, 0.43 percent improvement in net plant heat rate.
- 0.75 percent reduction in excess O_2: 0.27 percent gain in boiler efficiency, 0.60 percent improvement in net plant heat rate.

Utilization of a specific Vista model of Brown 2 would result in improved heat rate benefit estimates and should be considered as a next-phase effort. Hypothetically, it could be assumed that a modest reduction in boiler excess oxygen would be possible; therefore, if the unit could lower boiler outlet oxygen concentration by approximately 0.25 percent then the NPHR improvement would be about 0.23 percent. The effects on NPHR were not linear because they varied as a function of auxiliary power changes, as well as changes in steam temperatures, which were affected by reduced excess O_2 levels.

Total Installed Capital Cost:	$500,000
Heat Rate (efficiency) Improvement:	0.23%

3.6.3 F.B. Culley Unit 2 Neural Network Deployment

The unit has the ability to bias individual mills, and each burner has an air shroud that can be biased; fuel biasing is available at each burner. Also, there is no valid CO measurement; thus, the unit must be restricted to an arbitrary O_2 lower limit to avoid typical low oxygen combustion issues such as slagging and tube wastage.

Reducing excess oxygen levels in the boiler increases the boiler efficiency by reducing sensible heat losses, although in some cases, unburned carbon losses can be increased (but almost never more than the sensible heat losses are reduced). In addition, reducing excess oxygen levels improves the NPHR by reducing both FD and ID fan flow requirements and can also benefit emissions control systems performance.

The excess oxygen varies roughly from between 3.5 percent to 5.2 percent at gross output levels above 80 MW, with an average level approximating 4.3 percent. No online correlation of

NPHR or boiler efficiency from DCS system calculations was readily available from which to draw a plant-specific correlation, but from examining the plant air heater temperature data, boiler temperature data, and other factors, it was estimated by utilizing representative plant models within the EPRI Vista fuel quality impact model that reducing the excess oxygen would result in the following improvements to boiler efficiency and heat rate:

- 0.25 percent reduction in excess O_2: 0.15 percent gain in boiler efficiency, 0.26 percent improvement in net plant heat rate.
- 0.50 percent reduction in excess O_2: 0.29 percent gain in boiler efficiency, 0.47 percent improvement in net plant heat rate.
- 0.75 percent reduction in excess O_2: 0.43 percent gain in boiler efficiency, 0.62 percent improvement in net plant heat rate.

Utilization of a specific Vista model of F.B. Culley 2 would result in improved heat rate benefit estimates and should be considered as a next-phase effort. Hypothetically, it could be assumed that a modest reduction in boiler excess oxygen would be possible; therefore, if the unit could lower boiler outlet oxygen concentration by approximately 0.25 percent, then the NPHR improvement would be approximately 0.26 percent. The effects on NPHR were not linear because they varied as a function of auxiliary power changes, as well as changes in steam temperatures, which were affected by reduced excess O_2 levels.

Total Installed Capital Cost:	$500,000
Heat Rate (efficiency) Improvement:	0.26%

3.6.4 F.B. Culley Unit 3 Neural Network Deployment

The unit has the ability to bias individual mills, and each burner has an air shroud that can be biased; there is no fuel biasing available at each burner. Also, there is no valid CO measurement[5]; thus, the unit must be restricted to an arbitrary O_2 lower limit to avoid typical low oxygen combustion issues such as slagging and tube wastage.

Reducing excess oxygen levels in the boiler increases the boiler efficiency by reducing sensible heat losses, although in some cases, unburned carbon losses can be increased (but almost never more than the sensible heat losses are reduced). In addition, reducing excess oxygen levels improves the NPHR by reducing both FD and ID fan flow requirements and can also benefit emissions control systems performance. Plant personnel have commented that this could also help to control the O_2 balance across the furnace, which would yield better combustion control and help reduce slagging.

For F.B. Culley Unit 3, the excess oxygen varies roughly from between 2.5 percent to 4.2 percent at gross output levels above 270 MW, with an average level approximating 3.5 percent. No online correlation of net plant heat rate NPHR or boiler efficiency from DCS system calculations was

[5] Lack of a valid CO measurement would significantly hamper the ability of a neural network system to affect positive change in unit operations.

readily available to draw a plant-specific correlation, but from examining the plant air heater temperature data, boiler temperature data, and other factors, it was estimated by utilizing representative plant models within the EPRI Vista fuel quality impact model that reducing the excess oxygen would result in the following improvements to boiler efficiency and heat rate:

- 0.25 percent reduction in excess O_2: 0.13 percent gain in boiler efficiency, 0.25 percent improvement in net plant heat rate.
- 0.50 percent reduction in excess O_2: 0.24 percent gain in boiler efficiency, 0.46 percent improvement in net plant heat rate.
- 0.75 percent reduction in excess O_2: 0.32 percent gain in boiler efficiency, 0.62 percent improvement in net plant heat rate.

Utilization of a specific Vista model of F.B. Culley 3 would result in improved heat rate benefit estimates and should be considered as a next-phase effort. Hypothetically, it could be assumed that a modest reduction in boiler excess oxygen would be possible; therefore, if the unit could lower boiler outlet oxygen concentration by about 0.25 percent, then the NPHR improvement would be about 0.25 percent. The effects on NPHR were not linear because they varied as a function of auxiliary power changes, as well as changes in steam temperatures, which were affected by reduced excess O_2 levels.

Total Installed Capital Cost:	$500,000
Heat Rate (efficiency) Improvement:	0.25%

3.7 UNIT INTELLIGENT SOOTBLOWING DEPLOYMENT

The purpose of this project would be to reduce the required sootblowing flow by installing an integrated intelligent sootblowing (ISB) control system. This system would utilize heat flux sensors, hanger strain gauges, and process data to determine the areas needing to be cleaned. By cleaning only “dirty” areas, sootblowing flow would be reduced and tube life potentially extended.

3.7.1 A.B. Brown Unit 1 Intelligent Sootblowing Deployment

An ISB system will not be investigated for this unit because A.B. Brown Unit 1 already has ISB installed.

3.7.2 A.B. Brown Unit 2 Intelligent Sootblowing Deployment

An ISB system will not be investigated for this unit because A.B. Brown Unit 2 already has ISB installed.

3.7.3 F.B. Culley Unit 2 Intelligent Sootblowing Deployment

The plant uses air as the sootblowing media, but currently, no heat flux sensors or hanger strain gauges are installed. Sootblowing is currently based on operator observation, attemperation, and control operator judgement. In addition to current sootblower O&M, it is estimated that an ISB could reduce sootblowing by approximately 10 percent or greater.

Total Installed Capital Cost:	$350,000
Heat Rate (efficiency) Improvement:	0.10%

3.7.4 F.B. Culley Unit 3 Intelligent Sootblowing Deployment

An ISB system will not be investigated for this unit because F.B. Culley Unit 3 already has ISB installed.

3.8 IMPROVED O&M PRACTICES

The purpose of this project would be to improve O&M practices as they pertain to three particular areas of focus: heat rate improvement training, on-site appraisals for identifying additional heat rate improvements, and improved condenser cleaning strategies.

3.8.1 Heat Rate Improvement Training

Black & Veatch conducts heat rate awareness training, which covers the fundamentals of determining unit performance, how to use these metrics, and the operating conditions and decisions that impact unit efficiency and heat rate. The course includes numerous real-life case studies identified through years of monitoring and diagnostic work. This on-site course is typically 2.5 days and is primarily geared toward operators and engineers.

Total Installed Capital Cost	$15,000/class (could cover multiple units and plants)
Heat Rate (efficiency) Improvement:	Unknown, although improved O&M practices at peer coal fired EGUs have claimed to result in net plant heat rate improvements of 0.1 to 0.5 percent in the first year of implementation

3.8.2 On-Site Heat Rate Appraisals

On-site heat rate appraisals, mentioned as a BSER in the EPA ACE proposal, is left open to interpretation; indeed, the EPA was not able to provide suitable guidance for estimated ranges of capital cost or HRI. On-site heat rate appraisals are often conducted via a detailed assessment of controllable losses, especially those that can be reduced or eliminated by low-impact operations changes and equipment repairs and upgrades. This assessment utilizes a combination of a review and analysis of historical operations data, interviews with plant O&M personnel, review of past test and capability reports, a detailed study of the current fuel sources and fuel-related impacts upon the plant, discussions with plant management to understand the plant generation goals and objectives, and a reliability and maintenance history analysis.

Real-world examples of heat rate improvement projects resulting from on-site heat rate appraisals and audits include the following:

- Diagnosis of a cracked feedwater heater partition plate via analysis of online performance data, which resulted in a $12,000 monthly heat rate savings and 0.4 MW capacity improvement.
- Discovery of a failed reheat stop valve by analyzing reheat pressure swings over time, resulting in a $65,000 monthly heat rate improvement and 4 MW capacity improvement.
- An audit of terminal temperature difference (TTD) and drain cooler approach (DCA) temperature trends across a feedwater heater train at one power plant found that the highest-pressure feedwater heater emergency drain valve was leaking, with 50 percent of its flow returning to the condenser, rather than cascading to the next feedwater heater. This failure resulted in a heat rate loss of 53 Btu/kWh (about 0.5 percent and a net capacity loss of 2.5 MW.
- Testing of mill dirty air flows and coal flow balances at one power plant found that by rebalancing the flows on four mills to bring the coal and air flow deviation to within ± 10% (compared to the ± 30 percent it formerly operated at), coal unburned carbon heat losses decreased by 0.5 percent, which directly translated to an HRI of 0.5 percent. Moreover, burner-zone slagging was nearly eliminated by this change, resulting in significantly less use of sootblowing steam in the furnace wall blowers, which resulted in an additional long-term heat rate benefit of 0.1 percent (and a corresponding improvement in furnace wall tube life).
- Long-term analysis of subtle deviations in feedwater heater extraction lines revealed an internal line had failed, resulting in not only a $15,000 heat rate loss, but the potential for an unplanned outage because of debris in the heater.
- An analysis of 19 different truck coals supplied to a power plant found that not only were 7 of the coals unprofitable to burn, burning the worst coal resulted in a heat rate loss of more than 2 percent Moreover, this coal was responsible, in whole or in part, for the majority of the plant de-rates because of high-temperature sodium-based fouling, which cost the unit an additional 1.2 percent in heat rate on an annual basis because of the increased number of starts and stops from fouling-related outages.
- A long-term analysis of plant continuous emissions monitoring system (CEMS) data and motor amperage data found that a malfunctioning VFD controller in the coal handling system was responsible for incorrect blending of two different coals to meet the plant SO_2 limit, resulting in not only excess use of low-sulfur coal, but a loss of heat rate equating 0.6 percent on an annual basis.

Heat rate assessment is an ever-moving target, so while there is substantial benefit from a focused heat rate auditing and improvement program, long-term use of some type of performance and O&M monitoring system will provide the best overall heat rate improvement.

3.8.3 Improved Condenser Cleanliness Strategies

3.8.3.1 A.B. Brown Unit 1 Improved Condenser Cleaning Strategies

Condenser performance problems can be caused by any combination of many factors: tube sheet fouling, tube fouling, high number of plugged tubes, circulating water flow issues, waterbox priming, air in-leakage, and poor steam cycle isolation to condenser. Generally, plant data can provide clear evidence of condenser performance problems, but the causes may be difficult to discern.

To determine condenser performance, an energy balance was calculated between the boiler and turbine cycle. Gross generation data allowed the calculation of a gross turbine cycle heat rate and condenser heat duty. The condenser design data and industry standard condenser performance calculations were used to determine the actual operating condenser performance and calculate the expected back pressure. This allowed a comparison between actual and expected condenser back pressure. The turbine OEM back pressure correction curve was employed to calculate a heat rate impact for the difference between actual and expected back pressure. For every hour of operation in the remaining data set, the heat rate impact in $/hour was calculated with an assumed fuel cost of $2.50/MBtu, actual generation, and assumed boiler efficiency.

Condenser performance was reviewed over 1.3 years of operating data. The timing covered two summers and one winter. Condenser performance was calculated across load and across seasons. The working data set began with 8,500 hours of data. Nearly 8,000 hours of data (93 percent) were considered good quality and used for analysis. The range of unit load for the data set spanned 120 MW to 270 MW gross load. Low load operation (less than 175 MW gross) comprised 56 percent of the generation while high loads (less than 240 MW gross) accounted for 31 percent operating data.

From summer 2017 to summer 2018, the hourly average heat rate impact for condenser back pressure showed a significant change across the 2018 spring outage. Condenser performance during 2017 showed very poor performance at low loads. The expected back pressure across load for A.B. Brown Unit 1 is shown by the red trace on Figure 3-10. Actual unit back pressure is shown by the blue trace on this figure. Actual back pressure never falls below 3.3 in. HgA when the unit drops load. This yielded a high heat rate impact on average of 84 Btu/kWh, with an associated fuel cost of $37.00/h.

Figure 3-10 shows a “floor” in actual back pressure (blue) around 3.5 in. HgA in 2017. As unit load goes down, the back pressure should follow the red trend.

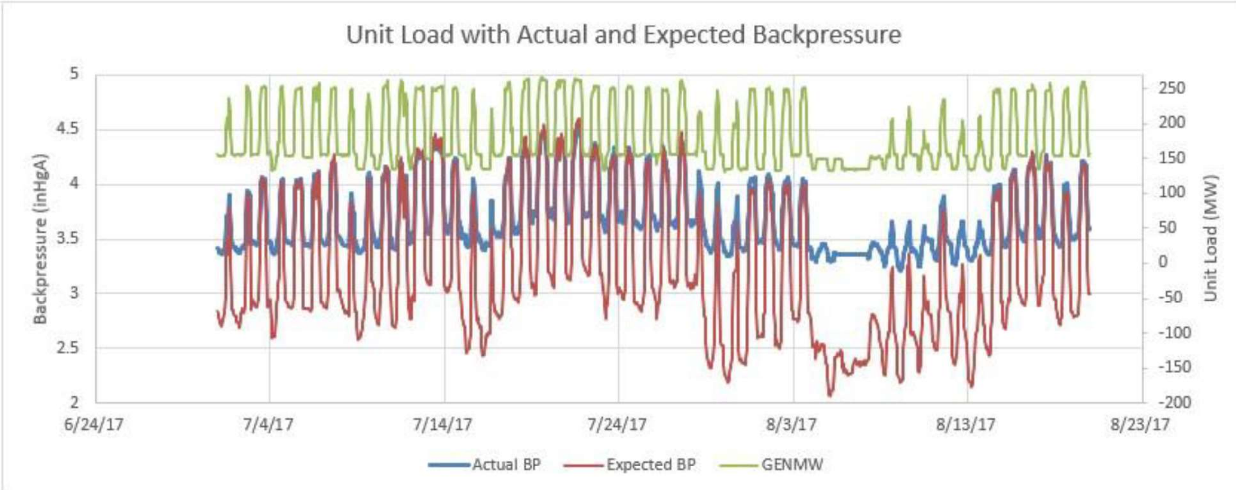


Figure 3-10 Summer 2017 Backpressure vs Time (the actual is shown in red and blue is expected performance.)

Figure 3-11 provides the perspective of actual and expected backpressure versus circulating water flow at low load. Back pressure deviations at low load for any unit can be significant.

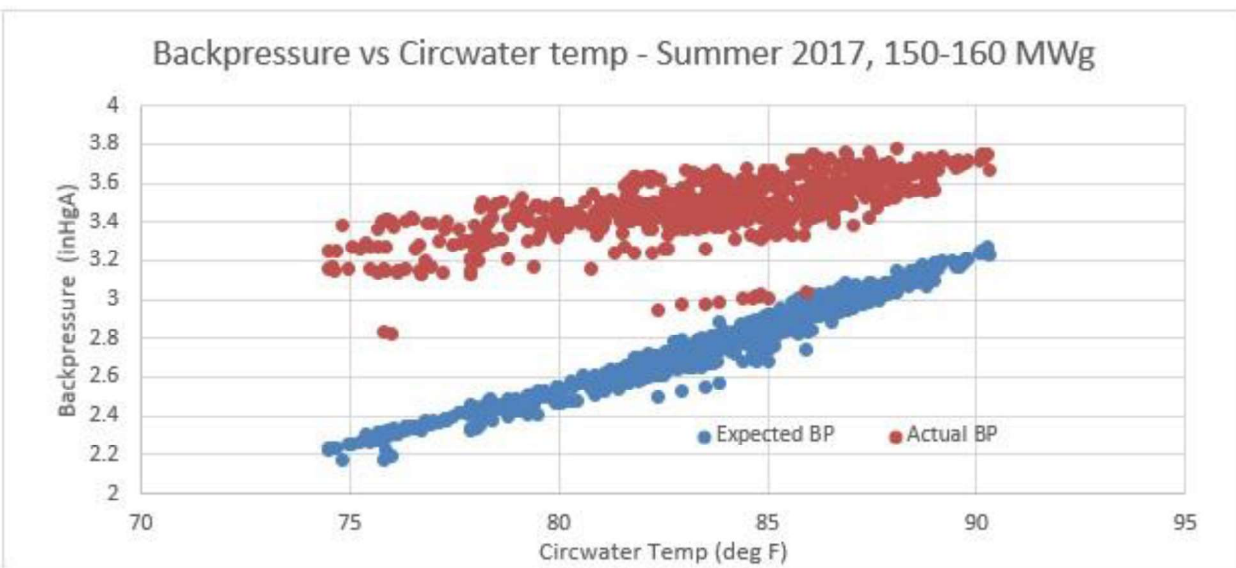


Figure 3-11 Poor Condenser Performance at Low Load 2017

When normal operation resumed in May of 2018, condenser performance looked good across load. The average heat rate impact from May to September of 2018 was estimated at 14 Btu/kWh, with a fuel-based heat rate cost of $5.7/h.

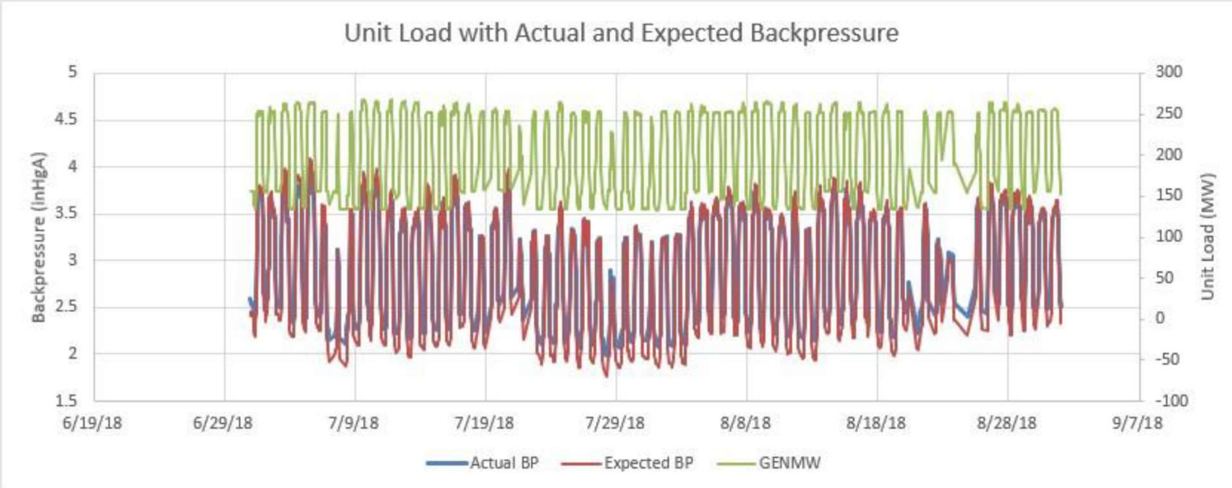


Figure 3-12 2018 Post Outage Actual and Expected Backpressure Over Time

On Figure 3-13 and 3-14, this actual back pressure is much closer to expected values in 2018. The remaining heat rate impact after the outage is likely to be due to the remaining gap in condenser performance at low load.

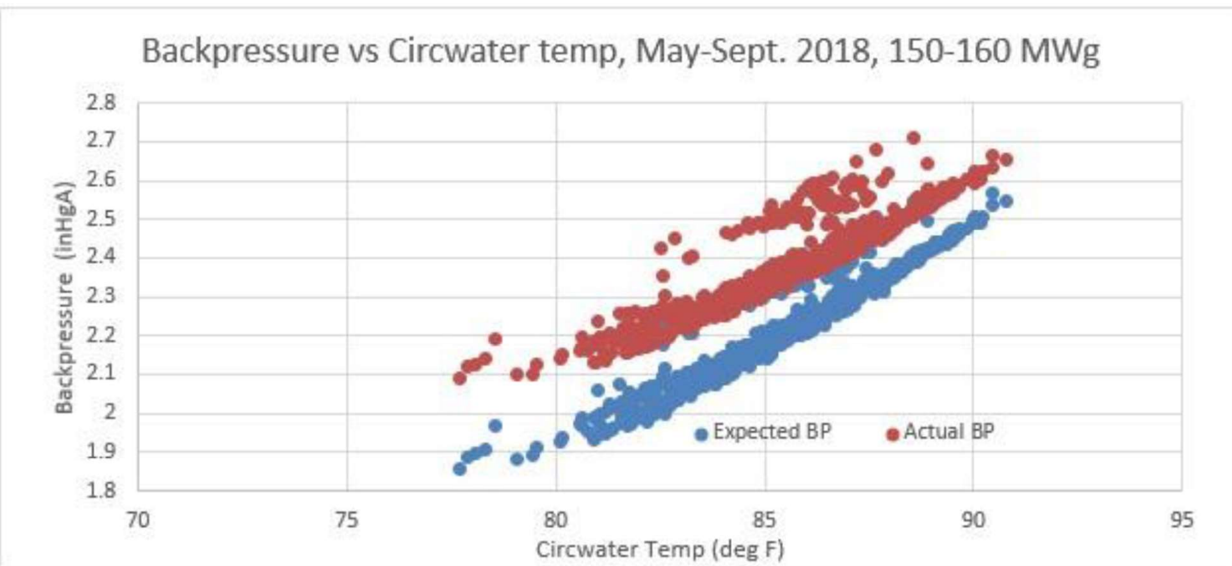


Figure 3-13 2018 Post Outage Performance at Low Load vs Circulating Water Outlet Temperature

Another noted change in condenser operation looking at both summers was calculated circulating water flow rate. Through the summer of 2017, average circulating water flow estimates were typically more than 25 percent below the design circulating water flow rate of 124,000 gpm. After the 2018 spring outage, estimated circulating water flow at full unit load was consistently 145,000 gpm, which is well above design. The estimated flow is sensitive to field measured circulating water temperatures and may need closer inspection.

The combination of these changes suggests significant air in-leakage or air removal improvements were made on the steam side, and water condenser cleaning yielded higher circulating water flows. According to plant personnel, they have repaired steam seal piping internal to the condenser neck. This issue has been appearing more regularly, and F.B. Culley 3 has had to perform similar repairs twice in the last two years. Across the span of the 15 months of operating data at full load, condenser performance was generally good, with cleanliness values at or above 70 percent as shown on Figure 3-14. However, because of low load performance problems, a fuel-based cost for 2017 operation is estimated to be $230,000 on an annual basis. Following the spring 2018 outage, the small deviation from expected condenser performance yields an estimated annual fuel cost of $35,000 on an annual basis. On the basis of the outage improvements seen in 2018, regularly scheduled maintenance and trending of performance should be sufficient to maintain good condenser performance.

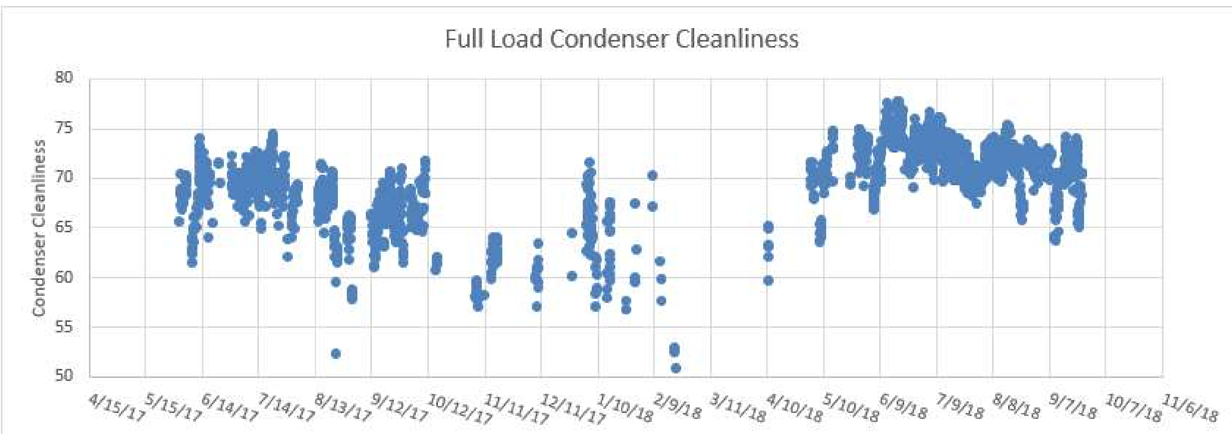


Figure 3-14 Full Load Cleanliness Results Over Time

3.8.3.2 A.B. Brown Unit 2 Improved Condenser Cleaning Strategies

Condenser performance was reviewed over 1.3 years of operating data. The timing covered two summers and one winter. Condenser performance was calculated across load and across seasons. In the process of reducing bad or suspicious data, 46 percent of the total data was removed. Nearly 6,000 hours of operating data ranging from 148 MW gross to full load was used for analysis.

Calculated results showed good performance for the condenser across load. It is suspected that measured back pressure readings may be biased low by approximately 0.2 to 0.3 in. HgA as actual back pressure consistently trended lower than expected and TTD at full load is unrealistically low (too good) at 3.5 to 5° F. The relationship between actual and expected back pressure versus circulating water temperature at constant load can be seen on Figure 3-15. As a result, condenser cleanliness values at full load consistently run greater than 90 percent and more than 100 percent at lower loads. Calculated circulating water flow rate is stable with estimated flows between

110,000 and 120,000 gpm. This is slightly below the design value of 124,000 gpm. Temperature rise across the condenser at full load runs 22° F versus design values of 20° F.

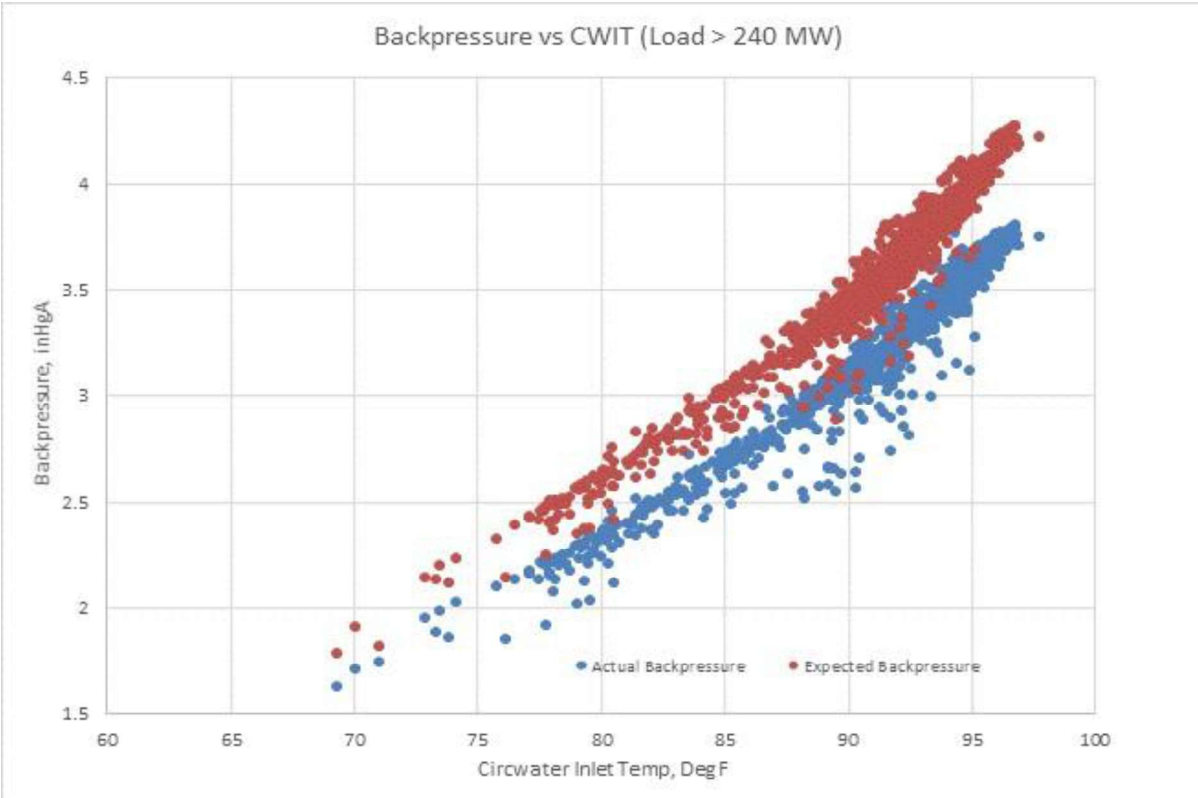


Figure 3-15 Condenser Back Pressure Versus Circulating Water Temperature at High Load

Generally, back pressure trended well across load during summer of 2017 and 2018. Separate trends of condenser performance behavior for summer 2017 and summer 2018 are provided on Figure 3-16 and Figure 3-17.

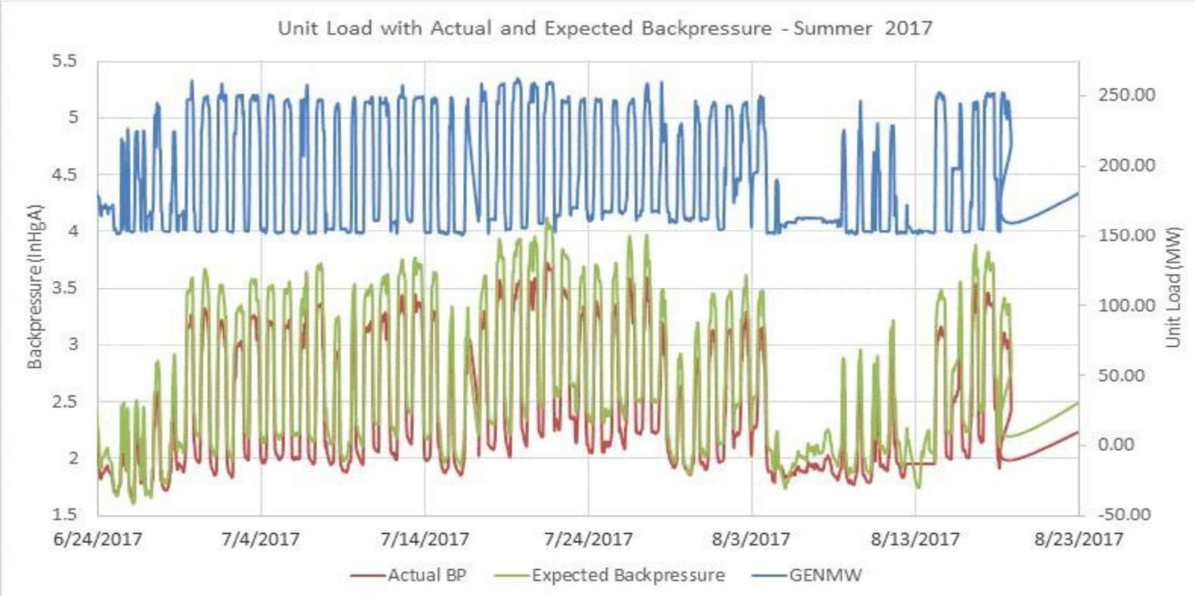


Figure 3-16 Condenser Performance Summer 2017 Across Load

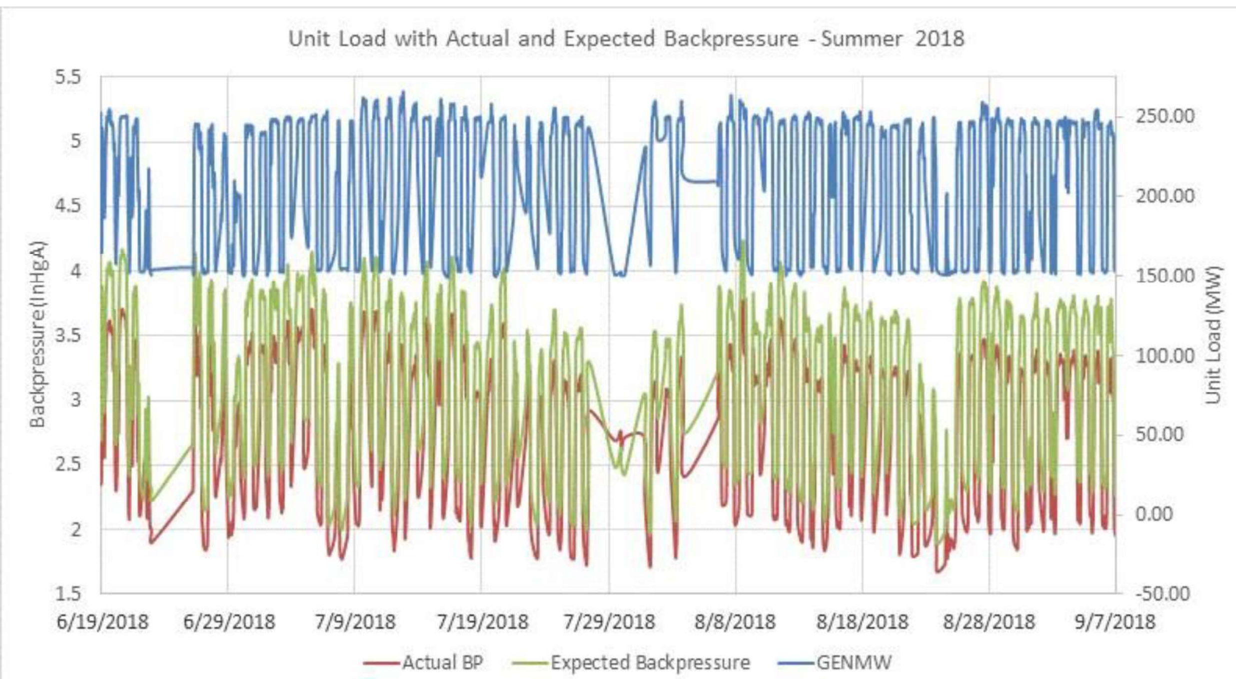


Figure 3-17 Condenser Performance Summer 2018 Across Load

Because the actual back pressure trends better than expected, no heat rate penalty is associated with normal unit operation for the data reviewed. Regularly scheduled maintenance and tracking of performance to highlight changes should be enough to maintain good condenser performance. For improved fidelity and confidence in performance metrics, the measured back pressure indication should be checked for accuracy and proper installation. The addition of more circulating water temperature measurements leaving the condenser would also improve accuracy of results by better capturing temperature stratification in the return piping.

3.8.3.3 F.B. Culley Unit 2 Improved Condenser Cleaning Strategies

For this study, 2 years of plant data were reviewed. Condenser performance was calculated across load and across seasons. Significant data reduction was necessary to eliminate offline or suspect data. This yielded more than 4,800 hours of operating data to characterize operation. In this data set, nearly 60 percent of the operating data were part load operation below 70 MW gross. Just over 30 percent of the data represented loads greater than 90 MW gross.

The hourly average heat rate impact of high condenser back pressure for Unit 2 is $42/h. Assuming the unit operates for 70 percent of a calendar year, this equates to a fuel cost of $257,000 per year. The average cleanliness value for Unit 2 is 28 percent. The highest achieved cleanliness values were in the low 50 percent range. The most significant observation with this analysis is shown on Figure 3-18 and is typical for the unit operation. Back pressure should have a strong load dependency. The Unit 2 back pressure data does not follow the expected pattern. The most likely cause of this behavior is significant air in-leakage or inadequate air removal system performance or limited capacity. Two additional factors are that Unit 2 relies upon steam jet air ejectors for air removal, and there is a suspected large air in-leakage around the turbine that has been present for years and has never been successfully resolved.

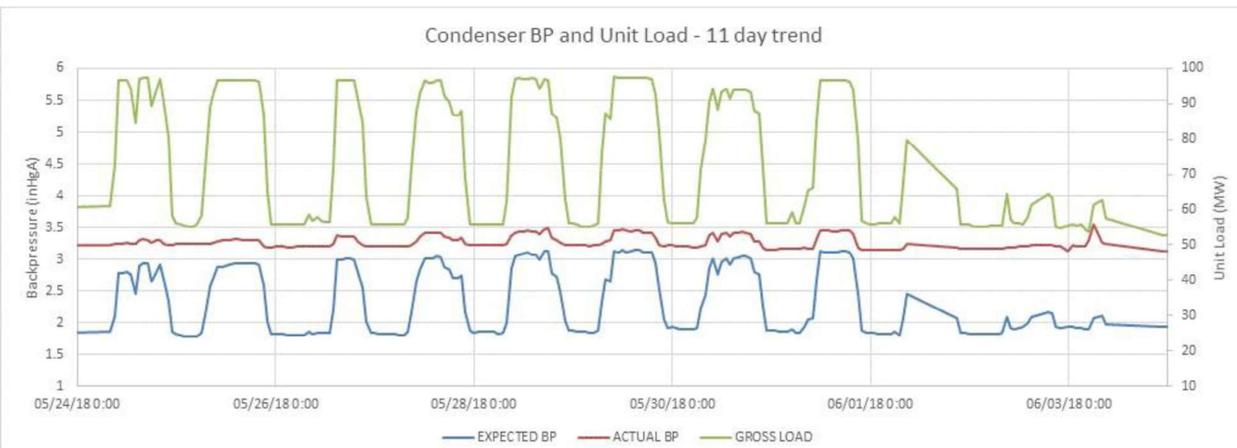


Figure 3-18 Condenser Back Pressure Versus Time (11 Day Trend)

The expected back pressure is calculated assuming no condenser tubes are plugged and cleanliness of 70 percent. Circulating water flow rate is calculated based on actual heat duty and circulating water temperature rise. Looking at full load operations across all season, there is a notable gap between actual and expected back pressure. This is shown on Figure 3-19, which illustrates back pressure versus circulating water temperature and versus time in Figure 3-20. The primary driver is expected to be the same issue of steam side air binding inhibiting lower backpressure at low circulating water temperatures.

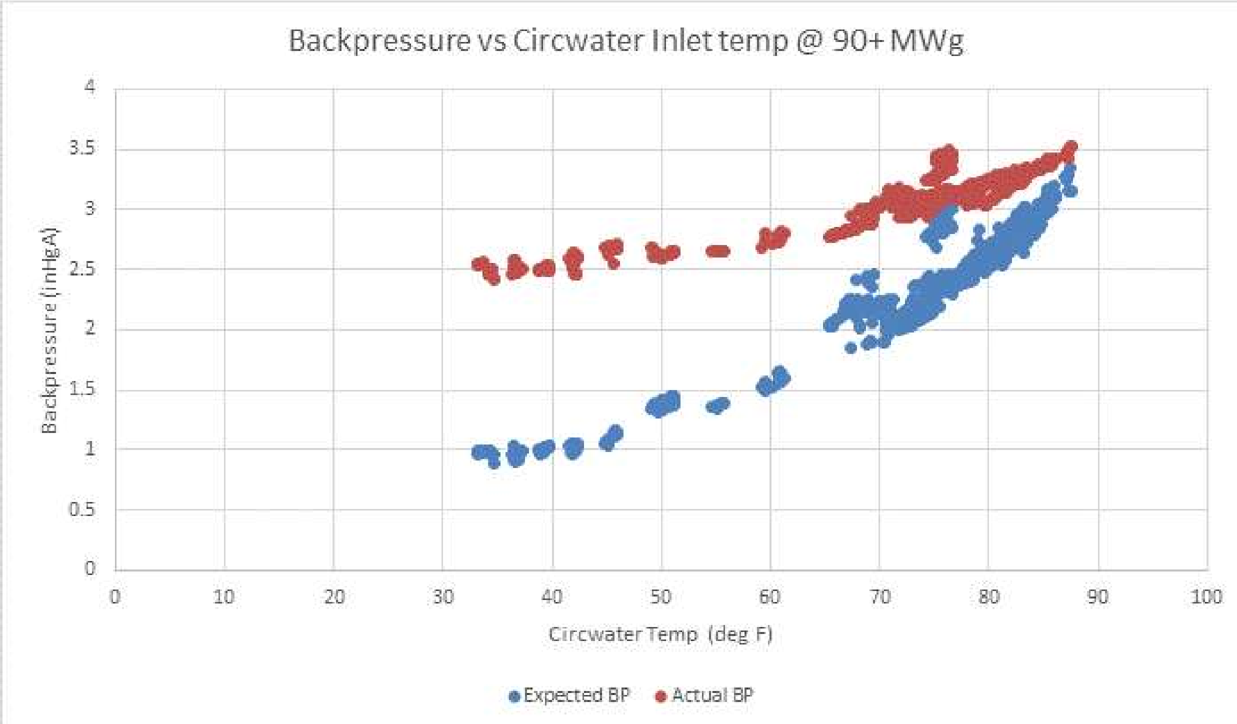


Figure 3-19 Condenser Back Pressure Versus Circulating Water Temperature

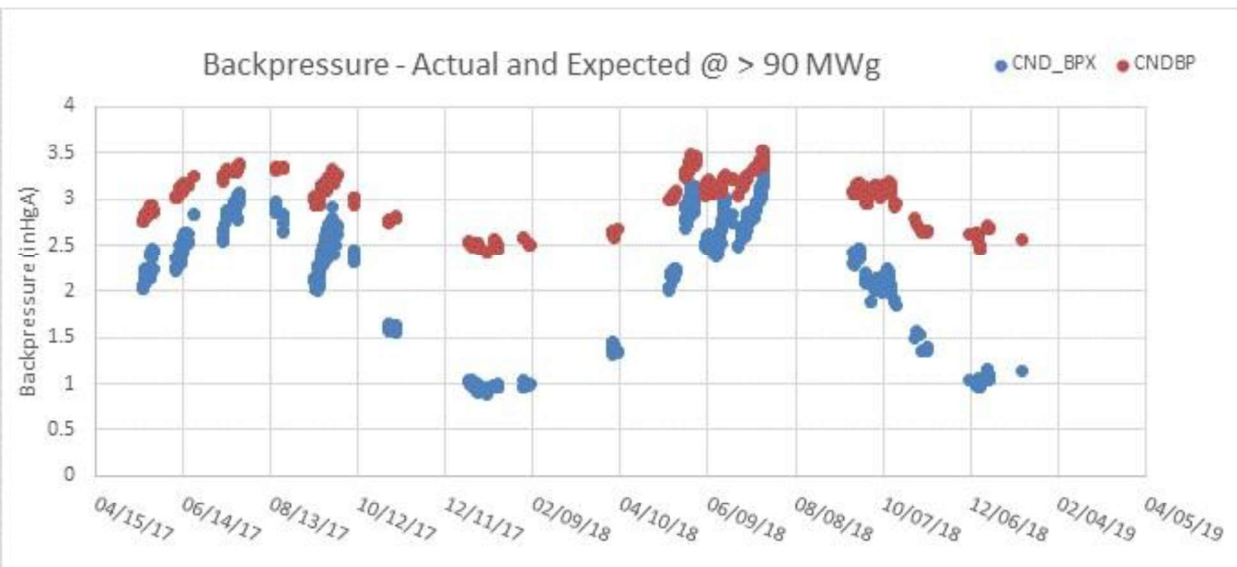


Figure 3-20 Back Pressure Versus Time (2-year trends)

3.8.3.4 F.B. Culley Unit 3 Improved Condenser Cleaning Strategies

The review of operating data for Unit 3 included 1.8 years of operational data. Data reduction to eliminate offline or suspect data eliminated 20 percent of the data, yielding more than 12,700 hours of data. The load used for analysis ranged from 135 MW gross up to 289 MW gross.

The hourly average heat rate impact of high condenser back pressure across all loads was 42 Btu/kWh and $24.8/h. Based on the data set for this analysis, the unit was in operation 90 percent of the time. Assuming this level of availability on an annual basis, the fuel cost associated with poor condenser performance is conservatively estimated at $196,000 per year. Load derates caused by high back pressure limits are probable for this unit, but highly variable, depending on the turbine design and manufacturer recommendation. Given the emphasis on efficiency opportunity in this report, an estimate for potential load impacts is not considered in this evaluation.

The highest sustained cleanliness value was slightly above 60 percent, with significant decay in performance lasting 9 of the 22 months, as seen on Figure 3-21.

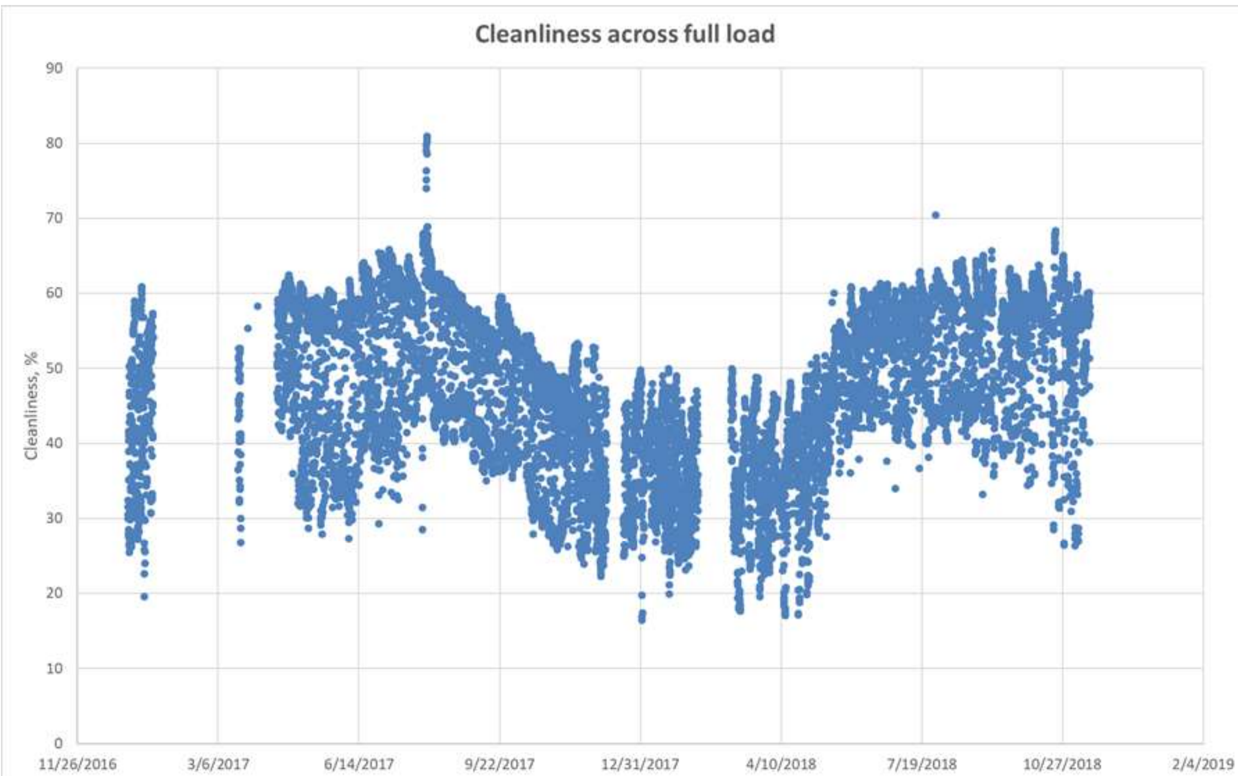


Figure 3-21 Condenser Cleanliness Across Time and Load

On closer look at the operating data, the repeated trend of increasing back pressure suggests significant tube sheet and or tube fouling issues on Figure 3-22.

Figure 3-22 Condenser Performance – 11 Day Trend

On Figure 3-23 and 3-24, a trend of back pressure versus circulating water inlet temperature at high load shows a mixture of good performance and very poor performance, especially at lower river temperatures.

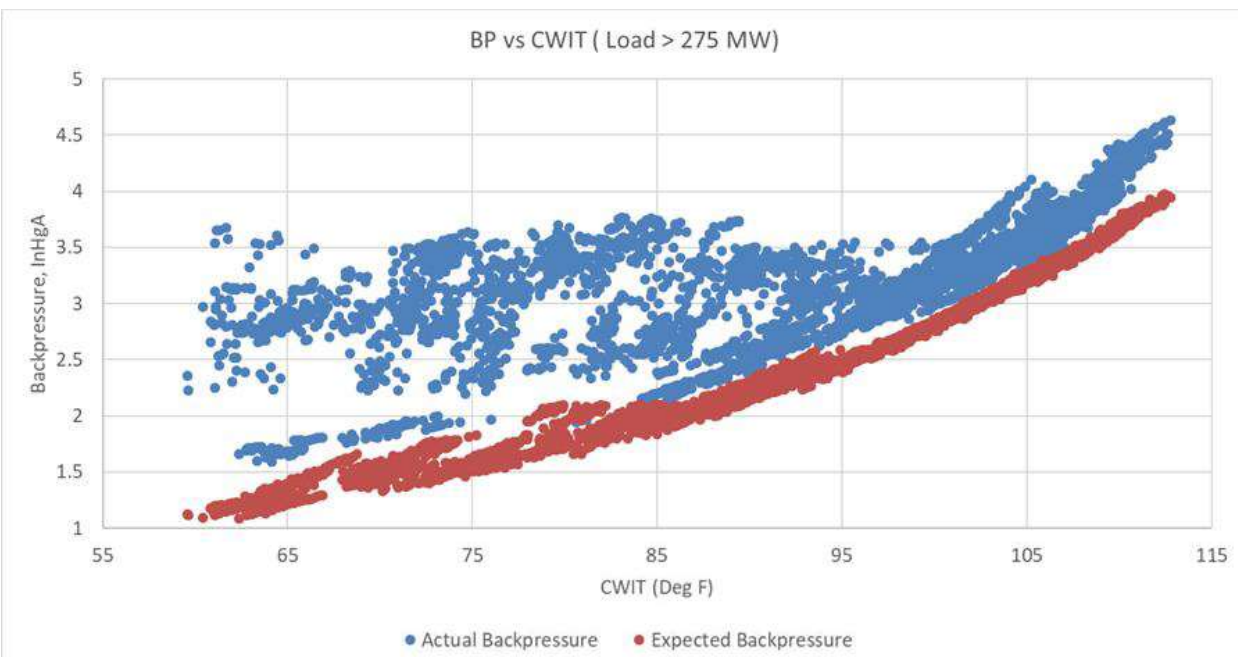


Figure 3-23 Condenser Back Pressure Versus Circulating Water Inlet Temperature

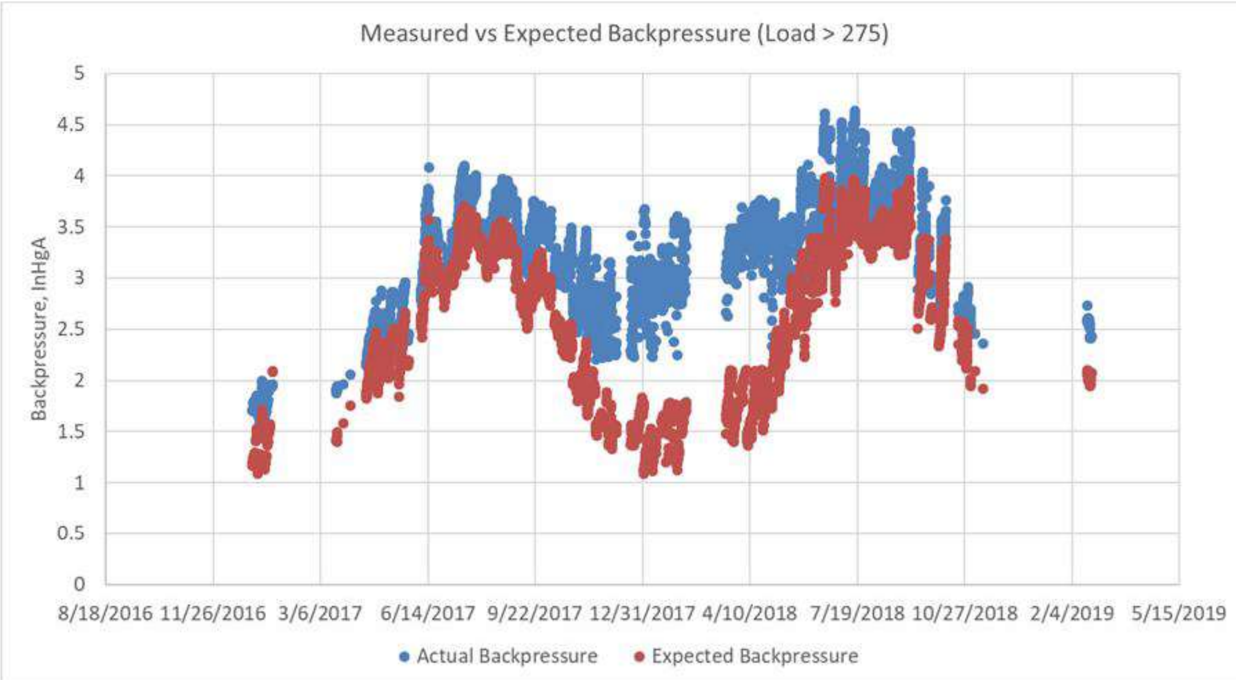


Figure 3-24 Condenser Back Pressure Versus Time at High Load

Condenser performance problems are unique to each unit and can be caused by a combination of factors. Considering the high availability, load capacity, and extent of condenser performance issues, this unit could be a candidate for added focus for improvement. If fouling the condenser is the primary concern felt by O&M personnel, payback on capital expenditure to rectify the situation may be too long, given this fuel cost. Adding backwash capability is likely to be cost prohibitive because of proximity of major piping work that would be required close to the turbine foundation. The addition of a debris filtering system would be beneficial and would be required before possible consideration of a ball cleaning system. The combined cost of these two capital improvements would likely be cost prohibitive.

4.0 Performance and CO_2 Production Estimates

High-level plant performance estimates were used to estimate the average annual CO_2 reduction. These performance benefits are summarized in Appendix B, Table B-1, Table B-2, Table B-3, and Table B-4, for A.B. Brown Unit 1, A.B. Brown Unit 2, F.B. Culley Unit 2, and F.B. Culley Unit 3, respectively. It should be noted that some projects will have overlapping performance impacts and benefits, so that the overall net benefit for a series of projects considered together will likely differ from the sum of the individual project benefits listed in each table.

The annual CO_2 production estimates shown in Tables 4-1 through 4-4 were based on the following plant performance basis. Net capacity, capacity factor, and the average annual net plant heat rate were provided by average annual values from the most recent full year data (2017) provided by SNL and Ventyx Velocity data.

Table 4-1 Basis for A.B. Brown Unit 1 CO_2 Reduction Estimates

GROSS/NET CAPACITY (MW)	NET CAPACITY FACTOR (%)	AVERAGE ANNUAL NET PLANT HEAT RATE (BTU/KWH)	FUEL HEAT INPUT (MBTU/Y)	LB CO_2/ MBTU (HHV)	ANNUAL CO_2 (TONS/Y)
265/248	43.7	11,575	11,427,186	205.2	1,172,428

Table 4-2 Basis for A.B. Brown Unit 2 CO_2 Reduction Estimates

GROSS/NET CAPACITY (MW)	NET CAPACITY FACTOR (%)	AVERAGE ANNUAL NET PLANT HEAT RATE (BTU/KWH)	FUEL HEAT INPUT (MBTU/Y)	LB CO_2/ MBTU (HHV)	ANNUAL CO_2 (TONS/Y)
265/248	45.7	11,007	11,554,139	205.2	1,185,450

Table 4-3 Basis for F.B. Culley Unit 2 CO_2 Reduction Estimates

GROSS/NET CAPACITY (MW)	NET CAPACITY FACTOR (%)	AVERAGE ANNUAL NET PLANT HEAT RATE (BTU/KWH)	FUEL HEAT INPUT (MBTU/Y)	LB CO_2/ MBTU (HHV)	ANNUAL CO_2 (TONS/Y)
104/90	22.2	12,639	2,395,298	205.0	245.523

Table 4-4 Basis for F.B. Culley Unit 3 CO_2 Reduction Estimates

GROSS/NET CAPACITY (MW)	NET CAPACITY FACTOR (%)	AVERAGE ANNUAL NET PLANT HEAT RATE (BTU/KWH)	FUEL HEAT INPUT (MBTU/Y)	LB CO_2/ MBTU (HHV)	ANNUAL CO_2 (TONS/Y)
287/270	70.5	10,552	20,885,900	205.1	2,141,818

Where:

Fuel Heat Input [MBtu/y] =

Net Capacity [MW] * 1,000 kW/MW * Capacity Factor [%] * 8,760 h/y * NPHR [Btu/kWh, HHV]/ (1,000,000 Btu/MBtu)

Annual CO_2 Production [tons/y] =

Fuel Heat Input [MBtu/y] * CO_2 Production Rate [CO_2 emissions, lbm/MBtu of Fuel Burned]/ (2,000 lbm/ ton)

5.0 Capital Cost Estimates

High-level capital cost estimates were developed for each alternative and are detailed with each HRI project in Section 3.0. These estimates are summarized in Appendix B, Tables B-1, B-2, B-3, and B-4 and are based on the information available and should be considered preliminary for comparative purposes. The estimates are on an overnight basis (exclusive of escalation). The estimates represent the total capital requirement for each project, assuming a turnkey EPC project execution strategy. Pricing was based on similar project pricing or Black & Veatch's internal database. Black & Veatch has not developed preliminary equipment sizing or layouts to determine the feasibility of adding the proposed equipment or performing the modifications that will be required to support their installation. More detailed evaluations will be required to verify, refine, and confirm the viability of any of the proposed projects that require equipment modification or additional area.

6.1 Project Risk Considerations

Factors that influence the ability to maintain power plant efficiency and corresponding CO_2 emissions reductions on an annual basis are discussed in this section.

6.2 EFFICIENCY DIFFERENCES DUE TO OPERATING PROFILE

Efficiency is significantly affected when plants operate under off-design conditions, particularly part-load operation or with frequent starts. The future operating characteristics of A.B. Brown Unit 1, A.B. Brown Unit 2, F.B. Culley Unit 2, and F.B. Culley Unit 3 can have a significant impact on the ability to achieve the expected efficiency gains and associated reduced CO_2 emissions.

6.2.1 Operating Load and Load Factor

Plants that operate with a low average output will have lower efficiency than their full-load design efficiency. Load or capacity factor describes the plant output over a period of time relative to the potential maximum; it depends on both running time at a given load and the operating load. Therefore, annual variation in both operating load and load factor can alter the CO_2 emissions as well as the benefit of capital projects intended to reduce plant emissions. Variation in the unit load factor can significantly impact the annual CO_2 emissions for a given generation rate.

Capital projects that may offer benefit in reducing outage duration or frequency may also see some benefit mitigated. For example, a plant may be able to extend the time between major overhauls and shorten the time required for a major overhaul of the steam turbine because of improved design. However, this could increase the hours the plant may run in a year and could increase the annual CO_2 emissions. Plant generation may be limited to avoid exceeding annual CO_2 emissions rates, negating some of the potential benefit of the upgrade.

6.2.2 Transient Operation

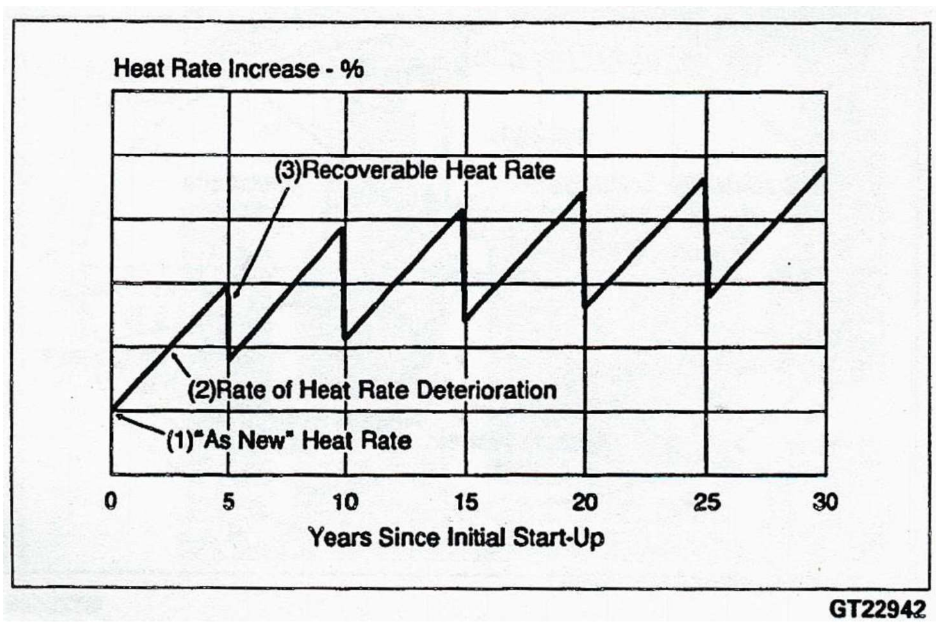
The greater the number of transients from steady state operating conditions that the plant experiences, the greater the impact to annual efficiency. During each of these transients, the plant will not be operating at peak performance. The influence of increasing renewable energy can affect the frequency of transient operation. Operation in frequency response mode, where steam flow and boiler firing fluctuate to regulate system frequency, can lead to more transients. Other situations may require frequent load changes, notably in response to power system constraints or power market pricing.

6.2.3 Plant Starts

Frequent shutdowns incur significant off-load energy losses, particularly during subsequent plant startup. Power plants operating in volatile or competitive markets, or operating as marginal providers of power, may be required to shut down frequently. This can also lead to deterioration in equipment condition, which will further affect annual plant efficiency and increase CO_2 emissions.

6.3 DETERIORATION

Figure 6-1 illustrates the characteristic performance deterioration that the steam turbine can be expected to experience between major overhauls. In addition, the ability of the steam turbine to economically recover from any deterioration in performance during a regularly scheduled maintenance overhaul is also illustrated. Any steam turbine retrofit is expected to experience a similar pattern of increasing deterioration, where increasingly, a portion of this deterioration is not viably recovered, even following a major overhaul. Turbine suppliers recognize the importance of sustained efficiency and work to incorporate features that result in superior sustained efficiency. The degree to which deterioration can be minimized by new designs is in large part dependent on the current design and feasible proven options. The ability of the steam turbine to sustain efficiency is a significant factor in achieving year after year CO_2 reduction.



Source: Steam Turbine Sustained Efficiency, GER-3750C

Figure 6-1 Steam Turbine Generator Heat Rate Change Over Time

Other plant equipment is also expected to see performance deterioration over the operating life after capital projects are implemented. The degree of deterioration and the rate at which it occurs is difficult to predict and presents a risk to the longer-term ability of the plants to sustain their efficiency gains.

6.4 PLANT MAINTENANCE

As well as ensuring plant availability, a key requirement of plant maintenance is to maintain peak operating efficiency. Improved maintenance and component replacement and upgrading can reduce energy losses.

Any poorly performing auxiliary equipment or individual components that affect performance will also contribute to the overall deterioration of plant performance over time, compounding the effects of deterioration in major components, such as the steam turbine. While not an intended outcome, plant upgrades can also result in increased maintenance if the expected improvements cannot be not achieved without increased or more complicated plant maintenance. Tables B-1, B-2, B-3, and B-4 (Appendix B) include an order-of-magnitude rating of comparative operating and maintenance cost impact associated with each of the given projects.

6.5 FUEL QUALITY IMPACTS

Variation in fuel quality can have a significant impact on the boiler efficiency. Reduced boiler efficiency will increase the required fuel heat input for a given generation which will increase CO_2 emissions. Variation in fuel composition can also have an effect on the pounds of CO_2 emission/MBtu of fuel burned.

6.6 AMBIENT CONDITIONS

Variation in ambient conditions can affect the condenser operating pressure and the resulting steam turbine output. In particular, higher wet bulb temperatures can have a significant impact on plant heat rate. Variation in annual average turbine back pressure because of wet bulb will affect the expected benefits of several of the heat rejection and steam turbine capital improvement projects.

Appendix A. Abbreviations and Acronyms

°F	Degrees Fahrenheit
ACE	Affordable Clean Energy (Plan)
ADSP	Advanced Design Steam Path
AH	Air Heater
AQCS	Air Quality Control System
BSER	Best System of Emission Reduction
Btu	British Thermal Unit
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPP	Clean Power Plan
DCA	Drain Cooler Approach
DCS	Distributed Control System
EGU	Electric Generating Unit
EPA	United States Environmental Protection Agency
EPRI	Electric Power Research Institute
FD	Forced Draft
Ft	Feet
GE	General Electric
GHG	Greenhouse Gas
gpm	Gallons per minute
h	Hour
HHV	Higher Heating Value
hp	Horsepower
HP	High Pressure
HRI	Heat Rate Improvement
ID	Induced Draft
IGBT	Insulated-Gate Bipolar Transistor
in. HgA	Inches of Mercury – Absolute
IP	Intermediate Pressure
IRP	Integrated Resource Plan
ISB	Intelligent Sootblowing
kW	Kilowatt
kWh	Kilowatt hour
lbm	Pound
LP	Low Pressure
MBtu	Million British Thermal Units

MW	Megawatt
NO_x	Nitrogen Oxide
NP	Normal Pressure
NPHR	Net Plant Heat Rate
NSR	New Source Review
OEM	Original Equipment Manufacturer
PA	Primary Air
PJFF	Pulse Jet Fabric Filter
rpm	Revolutions per Minute
SLR	Selective Catalytic Reduction
SO_2	Sulfur Dioxide
STG	Steam Turbine Generator
TTD	Terminal Temperature Difference
VFD	Variable Frequency Drive
VWO	Valve Wide Open
y	Year

Appendix B. Capital Cost and Performance Estimates

Table B-1 A.B. Brown Unit 1 Preliminary EPC Capital Cost Estimate (in 2019 Dollars) and First Year Performance Benefits

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Steam Turbine	HP/IP Upgrades or Full Steam Path Upgrades	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Economizer	Redesign or Replacement	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Air Heater/Duct Leakage	Air Heater Basket, Seal, and Sector Plate Replacement	850	0.50	57.88	57,136	5,862	145.0	Low
Air Heater/Duct Leakage	Air Heater (Steam Coil) System Repairs	350	0.10	11.6	11,427	1,172	298.5	N/A
Variable Frequency Drive (VFD) Upgrades	Boiler Feed Pumps	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Circulating Water Pumps	2,100	N/A	N/A	N/A	N/A	N/A	Low
Variable Frequency Drive (VFD) Upgrades	Cooling Tower Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Forced Draft Fans	2,000	0.43	50.3	49,701	5,099	392.2	Low/Med
Variable Frequency Drive (VFD) Upgrades	Induced Draft Fans	2,900	2.39	276.50	272,973	28,007	103.5	Low
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.25% reduction in excess O_2)	500	0.23	26.6	26,283	2,697	185.4	Low
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.50% reduction in excess O_2)	500	0.43	49.77	49,137	5,041	99.2	N/A

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.75% reduction in excess O_2)	500.0	0.60	69.5	68,563	7,035	71.1	Low
Intelligent Soot Blowing (ISB)	Synchronized controlled sootblowing system designed to alleviate excessive use of steam, air or water that have a negative effect on heat rate.	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Improved O&M Practices	Heat rate improvement training.	15	0.30	34.7	34,282	3,517	4.3	Low
Improved O&M Practices	On-site heat rate appraisals.	Variable	Variable	N/A	N/A	N/A	N/A	Low
Improved O&M Practices	Improved Condenser Cleaning Strategies	N/A	0.15	17.4	17,141	1,759	N/A	Low

Table B-2 A.B. Brown Unit 2 Preliminary EPC Capital Cost Estimate (in 2019 Dollars) and First Year Performance Benefits

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Steam Turbine	HP/IP Upgrades or Full Steam Path Upgrades	Not Recommended	N/A	N/A	N/A	N/A	N/A	No change
Economizer	Redesign or Replacement	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Air Heater/Duct Leakage	Air Heater Basket, Seal, and Sector Plate Replacement	850	0.50	55.0	57,771	5,927	143.4	Low
Air Heater/Duct Leakage	Air Heater (Steam Coil) System Repairs	350	0.10	11.0	11,554	1,185	295.2	Low
Variable Frequency Drive (VFD) Upgrades	Boiler Feed Pumps	Not Recommended	N/A	N/A	N/A	N/A	N/A	Low
Variable Frequency Drive (VFD) Upgrades	Circulating Water Pumps	2,100	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Cooling Tower Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Forced Draft Fans	2,000	0.26	28.6	30,015	3,080	649.4	N/A
Variable Frequency Drive (VFD) Upgrades	Induced Draft Fans	2,900	1.33	146.3	153,608	15,760	184.0	Low
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.25% reduction in excess O_2)	500	0.23	25.3	26,575	2,727	183.4	Low/Med
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.50% reduction in excess O_2)	500	0.43	47.33	49,683	5,097	98.1	Low

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.75% reduction in excess O_2)	500	0.60	66.0	69,325	7,113	70.3	Low
Intelligent Soot Blowing (ISB)	Synchronized controlled sootblowing system designed to alleviate excessive use of steam, air or water that have a negative effect on heat rate.	Not Recommended	N/A	N/A	N/A	N/A	N/A	Low
Improved O&M Practices	Heat rate improvement training.	15	0.30	33.0	34,662	3,556	4.2	Low
Improved O&M Practices	On-site heat rate appraisals.	Variable	Variable	N/A	N/A	N/A	N/A	Low
Improved O&M Practices	Improved Condenser Cleaning Strategies	N/A	N/A	N/A	N/A	N/A	N/A	Low

Table B-3 F.B. Culley Unit 2 Preliminary EPC Capital Cost Estimate (in 2019 Dollars) and First Year Performance Benefits

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Steam Turbine	Full steam path upgrades.	10,400	1.4	176.9	33,534	3.44	3,025,611	No change
Economizer	Redesign or Replacement	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Air Heater/Duct Leakage	Air Heater Basket, Seal, and Sector Plate Replacement	476	0.50	63.2	11,976	1.23	387,744	Low
Air Heater/Duct Leakage	Air Heater (Steam Coil) System Repairs	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Boiler Feed Pumps	600	0.60	75.8	14,372	1.47	407,294	N/A
Variable Frequency Drive (VFD) Upgrades	Circulating Water Pumps	900	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Cooling Tower Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Forced Draft Fans	2,000	0.48	60.9	11,549	1.18	1,689,525	N/A
Variable Frequency Drive (VFD) Upgrades	Induced Draft Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.25% reduction in excess O_2)	500	0.26	32.9	6,228	0.64	783,257	Low/Med
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.50% reduction in excess O_2)	500	0.47	59.40	11,258	1.15	433,291	Low

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.75% reduction in excess O_2)	500	0.62	78.4	14,851	1.52	328,463	Low
Intelligent Soot Blowing (ISB)	Synchronized controlled sootblowing system designed to alleviate excessive use of steam, air or water that have a negative effect on heat rate.	350	0.10	12.64	2,395	0.25	1,425,528	Low
Improved O&M Practices	Heat rate improvement training.	15	0.30	37.9	7,186	0.74	20,365	Low
Improved O&M Practices	On-site heat rate appraisals.	Variable	Variable	N/A	N/A	N/A	N/A	N/A
Improved O&M Practices	Improved Condenser Cleaning Strategies	N/A	0.42	53.1	10,060	1.03	N/A	Low

Table B-4 F.B. Culley Unit 3 Preliminary EPC Capital Cost Estimate (in 2019 Dollars) and First Year Performance Benefits

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Steam Turbine	HP/IP upgrades	19,900	1.5	158.3	313,289	32,127	619.4	No change
Economizer	Major redesign with additional tube passes.	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Air Heater/Duct Leakage	Air Heater Basket, Seal, and Sector Plate Replacement	750	0.50	52.8	104,430	10,709	70.0	Low
Air Heater/Duct Leakage	Air Heater (Steam Coil) System Repairs	350	0.10	10.6	20,886	2,142	163	Low
Variable Frequency Drive (VFD) Upgrades	Boiler Feed Pumps	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Circulating Water Pumps	2,100	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Cooling Tower Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Variable Frequency Drive (VFD) Upgrades	Forced Draft Fans	2,000	0.51	54.3	107,412	11,015	181.6	N/A
Variable Frequency Drive (VFD) Upgrades	Induced Draft Fans	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.25% reduction in excess O_2)	500	0.25	26.4	52,215	5,355	93.4	Low/Med
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.50% reduction in excess O_2)	500	0.46	48.54	96,075	9,852	50.7	Low

Component	Project Description	Est Capital Cost ($000)	Heat Rate Reduction (%)	Heat Rate Reduction (Btu/kWh)	Total Annual First Year Fuel Reduction (MBtu/y)	First Year Annual CO_2 Reduction (Tons/y)	Capital Cost/Annual CO_2 Reduction - First Year ($/(Ton/y))	Average Annual O&M Cost Impact**
Neural Network	Neural network deployment for combustion control and boiler excess air reduction. (0.75% reduction in excess O_2)	500	0.62	65.4	129,493	13,279	37.7	Low
Intelligent Soot Blowing (ISB)	Synchronized controlled sootblowing system designed to alleviate excessive use of steam, air or water that have a negative effect on heat rate.	Not Recommended	N/A	N/A	N/A	N/A	N/A	N/A
Improved O&M Practices	Heat rate improvement training.	15	0.30	31.7	62,658	6,425	2.3	Low
Improved O&M Practices	On-site Heat Rate Appraisals	Variable	Variable	N/A	N/A	N/A	N/A	N/A
Improved O&M Practices	Improved Condenser Cleaning Strategies	N/A	0.44	46.4	91,898	9,424	#VALUE!	Low

Table B-5 Preliminary Fuel and O&M Cost Impacts Expansion, Including Useful Plant Life for all Units (Report – 5year)

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (5-year useful life)	Cost per ton of CO2 ($) (5-year useful Life)
ABB1	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	58	58,716	130.1	0	0	130.1	6.5	8.5	39.9	29.00
ABB1	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11.6	11,768	26.1	0	0	26.1	13.4	15.4	43.93310101	59.71
ABB1	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	420.0	N/A
ABB1	Induced Draft Fans	2021	2,900	2.2	254.65	258,330	572.2	-2	0	570.2	5.1	7.1	9.764152778	22.49
ABB1	Forced Draft Fans	2021	2,000	0.5	58	58,711	130.1	-2	0	128.1	15.6	17.6	271.9	68.23
ABB1	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.23	26.6	26,984	59.8	0	0	59.8	8.4	10.4	40.22590404	37.08
ABB1	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	50	50,489	111.8	0	0	111.8	4.5	6.5	-11.8	19.84
ABB1	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	69.5	70,504	156.2	0	0	156.2	3.2	5.2	-56.17667929	14.22
ABB1	Heat Rate Improvement Training.	2021	15	0.3	35	35,201	78.0	0	0	78.0	0.2	2.2	-75.0	0.85
ABB1	On-Site Heat Rate Appraisals.	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB1	Improved Condenser Cleaner Strategies	2021	N/A	0.2	17	17,651	39.1	0	0	39.1	N/A	N/A	N/A	N/A
ABB1	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-17,753	-39.3	0	N/A	-39.3	-19.1	-17.1	189.3	-75.26
ABB1	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-37,433	-82.9	0	N/A	-82.9	-13.0	-11.0	297.9	-50.94
ABB1	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-63,302	-140.2	0	N/A	-140.2	-10.0	-8.0	420.2	-39.15
ABB2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	55	58,348	129.2	0	0	129.2	6.6	8.6	40.8	29.00

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (5-year useful life)	Cost per ton of CO2 ($) (5-year useful Life)
ABB2	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11	11,670	25.8	0	0	25.8	13.5	15.5	44.15010234	59.71
ABB2	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	420.0	N/A
ABB2	Induced Draft Fans	2021	2,900	1.2	132.084	140,125	310.4	0	0	-2.0	-1,450.0	-1448.0	582	41.22
ABB2	Forced Draft Fans	2021	2,000	0.2	22	23,354	51.7	0	0	-2.0	-1,000.0	-998.0	402.0	170.59
ABB2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	3	25.3	26,840	59.5	0	0	59.5	8.4	10.4	40.54523538	2.84
ABB2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	47	50,211	111.2	0	0	111.2	4.5	6.5	-11.2	19.84
ABB2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	66	70,018	155.1	0	0	155.1	3.2	5.2	-55.09938596	14.22
ABB2	Heat Rate Improvement Training	2021	15	0.3	33	35,009	77.5	0	0	77.5	0.2	2.2	-74.5	0.85
ABB2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Improved Condenser Cleaner Strategies	2021	N/A	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-18,565	-41.1	0	N/A	-41.1	-18.2	-16.2	239.3250631	-100.34
ABB2	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-39,146	-86.7	0	N/A	-86.7	-12.4	-10.4	282.9	-47.39
ABB2	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-66,199	-146.6	0	N/A	-146.6	-9.5	-7.5	340.2219394	-27.96
FBC2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	476	0.5	63	12,782	28.3	0	0	28.3	16.8	18.8	66.9	16.24
FBC2	Circulating Water Pumps	2021	900	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	180	N/A
FBC2	Boiler Feed Pump	2021	600	0.6	76	15,337	34.0	-2	0	32.0	18.8	20.8	88.0	17.06
FBC2	Forced Draft Fans	2021	2,000	0.5	63.195	12,781	28.3	-2	0	26.3	76.0	78.0	373.6878337	68.23

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (5-year useful life)	Cost per ton of CO2 ($) (5-year useful Life)
FBC2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.3	33	6,654	14.7	0	0	14.7	33.9	35.9	85.3	32.81
FBC2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.47	59.4	12,014	26.6	0	0	26.6	18.8	20.8	73.38804211	18.15
FBC2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	78	15,856	35.1	0	0	35.1	14.2	16.2	64.9	13.76
FBC2	Synchronized Controlled Sootblowing System	2021	350	0.1	12.64	2,556	5.7	0	0	5.7	61.8	63.8	64.33711872	59.71
FBC2	Heat Rate Improvement Training	2021	15	0.3	38	7,665	17.0	0	0	17.0	0.9	2.9	-14.0	0.85
FBC2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC2	Improved Condenser Cleaner Strategies	2021	N/A	0.4	53	10,740	23.8	0	0	23.8	N/A	N/A	N/A	N/A
FBC3	HP/IP Upgrades	2022	19,900	1.5	158.3	280,580	621.5	0	0	621.5	32.0	35.0	3358.478728	226.31
FBC3	Air Heater Basket, Seal, and Sector Plate Replacement	2022	750	0.5	53	93,586	207.3	0	0	207.3	3.6	6.6	-57.3	25.59
FBC3	Air Heater (Steam Coil) System Repairs	2022	350	0.1	10.6	18,788	41.6	0	0	41.6	8.4	11.4	28.38202472	59.71
FBC3	Circulating Water Pumps	2022	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	420.0	N/A
FBC3	Forced Draft Fans	2022	2,000	0.46	48.5392	86,034	190.6	-2	0	188.6	10.6	13.6	211.424224	74.17
FBC3	Neural Network with 0.25% Reduction in Excess O_2	2022	500	0.3	26	46,793	103.7	0	0	103.7	4.8	7.8	-3.7	34.12
FBC3	Neural Network with 0.50% Reduction in Excess O_2	2022	500	0.46	48.54	86,035	190.6	0	0	190.6	2.6	5.6	-90.57891699	18.54

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (5-year useful life)	Cost per ton of CO2 ($) (5-year useful Life)
FBC3	Neural Network with 0.75% Reduction in Excess O_2	2022	500	0.6	65	115,919	256.8	0	0	256.8	1.9	4.9	-156.8	13.76
FBC3	Heat Rate Improvement Training	2022	15	0.3	31.7	56,187	124.5	0	0	124.5	0.1	3.1	-121.4613034	0.85
FBC3	On-Site Heat Rate Appraisals	2022	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC3	Improved Condenser Cleaner Strategies	2022	N/A	0.44	46.4	82,242	182.2	0	0	182.2	N/A	N/A	N/A	N/A
FBC3	Economizer (1 Tube Pass)	2022	750	-0.1	-14	-25,169	-55.8	0	195.0	139.2	5.4	8.4	10.8	70.12
FBC3	Economizer (2 Tube Pass)	2022	1,075	-0.28	-29.1	-51,578	-114.3	0	288.8	174.6	6.2	9.2	40.4	92.79
FBC3	Economizer (3 Tube Pass)	2022	1,400	-0.4	-45	-79,583	-176.3	0	382.6	206.3	6.8	9.8	73.7	117.78

Table B-6 Preliminary Fuel and O&M Cost Impacts Expansion, Including Useful Plant Life for all Units (Report –10 year)

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (10-year useful life)	Cost per ton of CO2 ($) (10-year useful Life)
ABB1	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	58	58,716	130.1	0	0	130.1	6.5	8.5	-45.1	14.50
ABB1	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11.6	11,768	26.1	0	0	26.1	13.4	15.4	8.9	29.85
ABB1	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	210.0	N/A
ABB1	Induced Draft Fans	2021	2,900	2.2	254.65	258,330	572.2	-2	0	570.2	5.1	7.1	-280.2	11.24
ABB1	Forced Draft Fans	2021	2,000	0.5	58	58,711	130.1	-2	0	128.1	15.6	17.6	71.9	34.12
ABB1	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.23	26.6	26,984	59.8	0	0	59.8	8.4	10.4	-9.8	18.54
ABB1	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	50	50,489	111.8	0	0	111.8	4.5	6.5	-61.8	9.92
ABB1	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	69.5	70,504	156.2	0	0	156.2	3.2	5.2	-106.2	7.11
ABB1	Heat Rate Improvement Training.	2021	15	0.3	35	35,201	78.0	0	0	78.0	0.2	2.2	-76.5	0.43
ABB1	On-Site Heat Rate Appraisals.	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB1	Improved Condenser Cleaner Strategies	2021	N/A	0.2	17	17,651	39.1	0	0	39.1	N/A	N/A	N/A	N/A
ABB1	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-17,753	-39.3	0	N/A	-39.3	-19.1	-17.1	114.3	-37.63
ABB1	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-37,433	-82.9	0	N/A	-82.9	-13.0	-11.0	190.4	-25.47
ABB1	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-63,302	-140.2	0	N/A	-140.2	-10.0	-8.0	280.2	-19.58

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (10-year useful life)	Cost per ton of CO2 ($) (10-year useful Life)
ABB2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	55	58,348	129.2	0	0	129.2	6.6	8.6	-44.2	14.50
ABB2	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11	11,670	25.8	0	0	25.8	13.5	15.5	9.2	29.85
ABB2	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	210.0	N/A
ABB2	Induced Draft Fans	2021	2,900	1.2	132.084	140,125	310.4	0	0	-2.0	-1,450.0	-1448.0	292.0	20.61
ABB2	Forced Draft Fans	2021	2,000	0.2	22	23,354	51.7	0	0	-2.0	-1,000.0	-998.0	202.0	85.29
ABB2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	3	25.3	26,840	59.5	0	0	59.5	8.4	10.4	-9.5	1.42
ABB2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	47	50,211	111.2	0	0	111.2	4.5	6.5	-61.2	9.92
ABB2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	66	70,018	155.1	0	0	155.1	3.2	5.2	-105.1	7.11
ABB2	Heat Rate Improvement Training	2021	15	0.3	33	35,009	77.5	0	0	77.5	0.2	2.2	-76.0	0.43
ABB2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Improved Condenser Cleaner Strategies	2021	N/A	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-18,565	-41.1	0	N/A	-41.1	-18.2	-16.2	139.3	-50.17
ABB2	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-39,146	-86.7	0	N/A	-86.7	-12.4	-10.4	182.9	-23.69
ABB2	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-66,199	-146.6	0	N/A	-146.6	-9.5	-7.5	240.2	-13.98

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (10-year useful life)	Cost per ton of CO2 ($) (10-year useful Life)
FBC2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	476	0.5	63	12,782	28.3	0	0	28.3	16.8	18.8	19.3	8.12
FBC2	Circulating Water Pumps	2021	900	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	90.0	N/A
FBC2	Boiler Feed Pump	2021	600	0.6	76	15,337	34.0	-2	0	32.0	18.8	20.8	28.0	8.53
FBC2	Forced Draft Fans	2021	2,000	0.5	63.195	12,781	28.3	-2	0	26.3	76.0	78.0	173.7	34.12
FBC2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.3	33	6,654	14.7	0	0	14.7	33.9	35.9	35.3	16.40
FBC2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.47	59.4	12,014	26.6	0	0	26.6	18.8	20.8	23.4	9.07
FBC2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	78	15,856	35.1	0	0	35.1	14.2	16.2	14.9	6.88
FBC2	Synchronized Controlled Sootblowing System	2021	350	0.1	12.64	2,556	5.7	0	0	5.7	61.8	63.8	29.3	29.85
FBC2	Heat Rate Improvement Training	2021	15	0.3	38	7,665	17.0	0	0	17.0	0.9	2.9	-15.5	0.43
FBC2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC2	Improved Condenser Cleaner Strategies	2021	N/A	0.4	53	10,740	23.8	0	0	23.8	N/A	N/A	N/A	N/A
FBC3	HP/IP Upgrades	2022	19,900	1.5	158.3	280,580	621.5	0	0	621.5	32.0	35.0	1,368.5	113.16
FBC3	Air Heater Basket, Seal, and Sector Plate Replacement	2022	750	0.5	53	93,586	207.3	0	0	207.3	3.6	6.6	-132.3	12.79
FBC3	Air Heater (Steam Coil) System Repairs	2022	350	0.1	10.6	18,788	41.6	0	0	41.6	8.4	11.4	-6.6	29.85

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (10-year useful life)	Cost per ton of CO2 ($) (10-year useful Life)
FBC3	Circulating Water Pumps	2022	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	210.0	N/A
FBC3	Forced Draft Fans	2022	2,000	0.46	48.5392	86,034	190.6	-2	0	188.6	10.6	13.6	11.4	37.08
FBC3	Neural Network with 0.25% Reduction in Excess O_2	2022	500	0.3	26	46,793	103.7	0	0	103.7	4.8	7.8	-53.7	17.06
FBC3	Neural Network with 0.50% Reduction in Excess O_2	2022	500	0.46	48.54	86,035	190.6	0	0	190.6	2.6	5.6	-140.6	9.27
FBC3	Neural Network with 0.75% Reduction in Excess O_2	2022	500	0.6	65	115,919	256.8	0	0	256.8	1.9	4.9	-206.8	6.88
FBC3	Heat Rate Improvement Training	2022	15	0.3	31.7	56,187	124.5	0	0	124.5	0.1	3.1	-123.0	0.43
FBC3	On-Site Heat Rate Appraisals	2022	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC3	Improved Condenser Cleaner Strategies	2022	N/A	0.44	46.4	82,242	182.2	0	0	182.2	N/A	N/A	N/A	N/A
FBC3	Economizer (1 Tube Pass)	2022	750	-0.1	-14	-25,169	-55.8	0	195.0	139.2	5.4	8.4	-64.2	35.06
FBC3	Economizer (2 Tube Pass)	2022	1,075	-0.28	-29.1	-51,578	-114.3	0	288.8	174.6	6.2	9.2	-67.1	46.40
FBC3	Economizer (3 Tube Pass)	2022	1,400	-0.4	-45	-79,583	-176.3	0	382.6	206.3	6.8	9.8	-66.3	58.89

Table B-7 Preliminary Fuel and O&M Cost Impacts Expansion, Including Useful Plant Life for all Units (Report –15 year)

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (15-year useful life)	Cost per ton of CO2 ($) (15-year useful Life)
ABB1	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	58	58,716	130.1	0	0	130.1	6.5	8.5	-73.4	9.67
ABB1	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11.6	11,768	26.1	0	0	26.1	13.4	15.4	-2.7	19.90
ABB1	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
ABB1	Induced Draft Fans	2021	2,900	2.2	254.65	258,330	572.2	-2	0	570.2	5.1	7.1	-376.9	7.50
ABB1	Forced Draft Fans	2021	2,000	0.5	58	58,711	130.1	-2	0	128.1	15.6	17.6	5.3	22.74
ABB1	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.23	26.6	26,984	59.8	0	0	59.8	8.4	10.4	-26.4	12.36
ABB1	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	50	50,489	111.8	0	0	111.8	4.5	6.5	-78.5	6.61
ABB1	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	69.5	70,504	156.2	0	0	156.2	3.2	5.2	-122.8	4.74
ABB1	Heat Rate Improvement Training.	2021	15	0.3	35	35,201	78.0	0	0	78.0	0.2	2.2	-77.0	0.28
ABB1	On-Site Heat Rate Appraisals.	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB1	Improved Condenser Cleaner Strategies	2021	N/A	0.2	17	17,651	39.1	0	0	39.1	N/A	N/A	N/A	N/A
ABB1	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-17,753	-39.3	0	N/A	-39.3	-19.1	-17.1	89.3	-25.09
ABB1	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-37,433	-82.9	0	N/A	-82.9	-13.0	-11.0	154.6	-16.98
ABB1	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-63,302	-140.2	0	N/A	-140.2	-10.0	-8.0	233.6	-13.05

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (15-year useful life)	Cost per ton of CO2 ($) (15-year useful Life)
ABB2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	55	58,348	129.2	0	0	129.2	6.6	8.6	-72.6	9.67
ABB2	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11	11,670	25.8	0	0	25.8	13.5	15.5	-2.5	19.90
ABB2	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
ABB2	Induced Draft Fans	2021	2,900	1.2	132.084	140,125	310.4	0	0	-2.0	-1,450.0	-1448.0	195.3	13.74
ABB2	Forced Draft Fans	2021	2,000	0.2	22	23,354	51.7	0	0	-2.0	-1,000.0	-998.0	135.3	56.86
ABB2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	3	25.3	26,840	59.5	0	0	59.5	8.4	10.4	-26.1	0.95
ABB2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	47	50,211	111.2	0	0	111.2	4.5	6.5	-77.9	6.61
ABB2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	66	70,018	155.1	0	0	155.1	3.2	5.2	-121.8	4.74
ABB2	Heat Rate Improvement Training	2021	15	0.3	33	35,009	77.5	0	0	77.5	0.2	2.2	-76.5	0.28
ABB2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Improved Condenser Cleaner Strategies	2021	N/A	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-18,565	-41.1	0	N/A	-41.1	-18.2	-16.2	106.0	-33.45
ABB2	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-39,146	-86.7	0	N/A	-86.7	-12.4	-10.4	149.6	-15.80
ABB2	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-66,199	-146.6	0	N/A	-146.6	-9.5	-7.5	206.9	-9.32

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (15-year useful life)	Cost per ton of CO2 ($) (15-year useful Life)
FBC2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	476	0.5	63	12,782	28.3	0	0	28.3	16.8	18.8	3.4	5.41
FBC2	Circulating Water Pumps	2021	900	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	60.0	N/A
FBC2	Boiler Feed Pump	2021	600	0.6	76	15,337	34.0	-2	0	32.0	18.8	20.8	8.0	5.69
FBC2	Forced Draft Fans	2021	2,000	0.5	63.195	12,781	28.3	-2	0	26.3	76.0	78.0	107.0	22.74
FBC2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.3	33	6,654	14.7	0	0	14.7	33.9	35.9	18.6	10.94
FBC2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.47	59.4	12,014	26.6	0	0	26.6	18.8	20.8	6.7	6.05
FBC2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	78	15,856	35.1	0	0	35.1	14.2	16.2	-1.8	4.59
FBC2	Synchronized Controlled Sootblowing System	2021	350	0.1	12.64	2,556	5.7	0	0	5.7	61.8	63.8	17.7	19.90
FBC2	Heat Rate Improvement Training	2021	15	0.3	38	7,665	17.0	0	0	17.0	0.9	2.9	-16.0	0.28
FBC2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC2	Improved Condenser Cleaner Strategies	2021	N/A	0.4	53	10,740	23.8	0	0	23.8	N/A	N/A	N/A	N/A
FBC3	HP/IP Upgrades	2022	19,900	1.5	158.3	280,580	621.5	0	0	621.5	32.0	35.0	705.1	75.44
FBC3	Air Heater Basket, Seal, and Sector Plate Replacement	2022	750	0.5	53	93,586	207.3	0	0	207.3	3.6	6.6	-157.3	8.53
FBC3	Air Heater (Steam Coil) System Repairs	2022	350	0.1	10.6	18,788	41.6	0	0	41.6	8.4	11.4	-18.3	19.90

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (15-year useful life)	Cost per ton of CO2 ($) (15-year useful Life)
FBC3	Circulating Water Pumps	2022	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
FBC3	Forced Draft Fans	2022	2,000	0.46	48.5392	86,034	190.6	-2	0	188.6	10.6	13.6	-55.2	24.72
FBC3	Neural Network with 0.25% Reduction in Excess O_2	2022	500	0.3	26	46,793	103.7	0	0	103.7	4.8	7.8	-70.3	11.37
FBC3	Neural Network with 0.50% Reduction in Excess O_2	2022	500	0.46	48.54	86,035	190.6	0	0	190.6	2.6	5.6	-157.2	6.18
FBC3	Neural Network with 0.75% Reduction in Excess O_2	2022	500	0.6	65	115,919	256.8	0	0	256.8	1.9	4.9	-223.4	4.59
FBC3	Heat Rate Improvement Training	2022	15	0.3	31.7	56,187	124.5	0	0	124.5	0.1	3.1	-123.5	0.28
FBC3	On-Site Heat Rate Appraisals	2022	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC3	Improved Condenser Cleaner Strategies	2022	N/A	0.44	46.4	82,242	182.2	0	0	182.2	N/A	N/A	N/A	N/A
FBC3	Economizer (1 Tube Pass)	2022	750	-0.1	-14	-25,169	-55.8	0	195.0	139.2	5.4	8.4	-89.2	23.37
FBC3	Economizer (2 Tube Pass)	2022	1,075	-0.28	-29.1	-51,578	-114.3	0	288.8	174.6	6.2	9.2	-102.9	30.93
FBC3	Economizer (3 Tube Pass)	2022	1,400	-0.4	-45	-79,583	-176.3	0	382.6	206.3	6.8	9.8	-113	39.26

Table B-8 Preliminary Fuel and O&M Cost Impacts Expansion, Including Useful Plant Life for all Units (Report –20 year)

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (20-year useful life)	Cost per ton of CO2 ($) (20-year useful Life)
ABB1	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	58	58,716	130.1	0	0	130.1	6.5	8.5	-73.4	9.67
ABB1	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11.6	11,768	26.1	0	0	26.1	13.4	15.4	-2.7	19.90
ABB1	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
ABB1	Induced Draft Fans	2021	2,900	2.2	254.65	258,330	572.2	-2	0	570.2	5.1	7.1	-376.9	7.50
ABB1	Forced Draft Fans	2021	2,000	0.5	58	58,711	130.1	-2	0	128.1	15.6	17.6	5.3	22.74
ABB1	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.23	26.6	26,984	59.8	0	0	59.8	8.4	10.4	-26.4	12.36
ABB1	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	50	50,489	111.8	0	0	111.8	4.5	6.5	-78.5	6.61
ABB1	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	69.5	70,504	156.2	0	0	156.2	3.2	5.2	-122.8	4.74
ABB1	Heat Rate Improvement Training.	2021	15	0.3	35	35,201	78.0	0	0	78.0	0.2	2.2	-77.0	0.28
ABB1	On-Site Heat Rate Appraisals.	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB1	Improved Condenser Cleaner Strategies	2021	N/A	0.2	17	17,651	39.1	0	0	39.1	N/A	N/A	N/A	N/A
ABB1	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-17,753	-39.3	0	N/A	-39.3	-19.1	-17.1	76.8	-18.81
ABB1	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-37,433	-82.9	0	N/A	-82.9	-13.0	-11.0	136.7	-12.73
ABB1	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-63,302	-140.2	0	N/A	-140.2	-10.0	-8.0	210.2	-9.79
ABB2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	850	0.5	55	58,348	129.2	0	0	129.2	6.6	8.6	-72.6	9.67

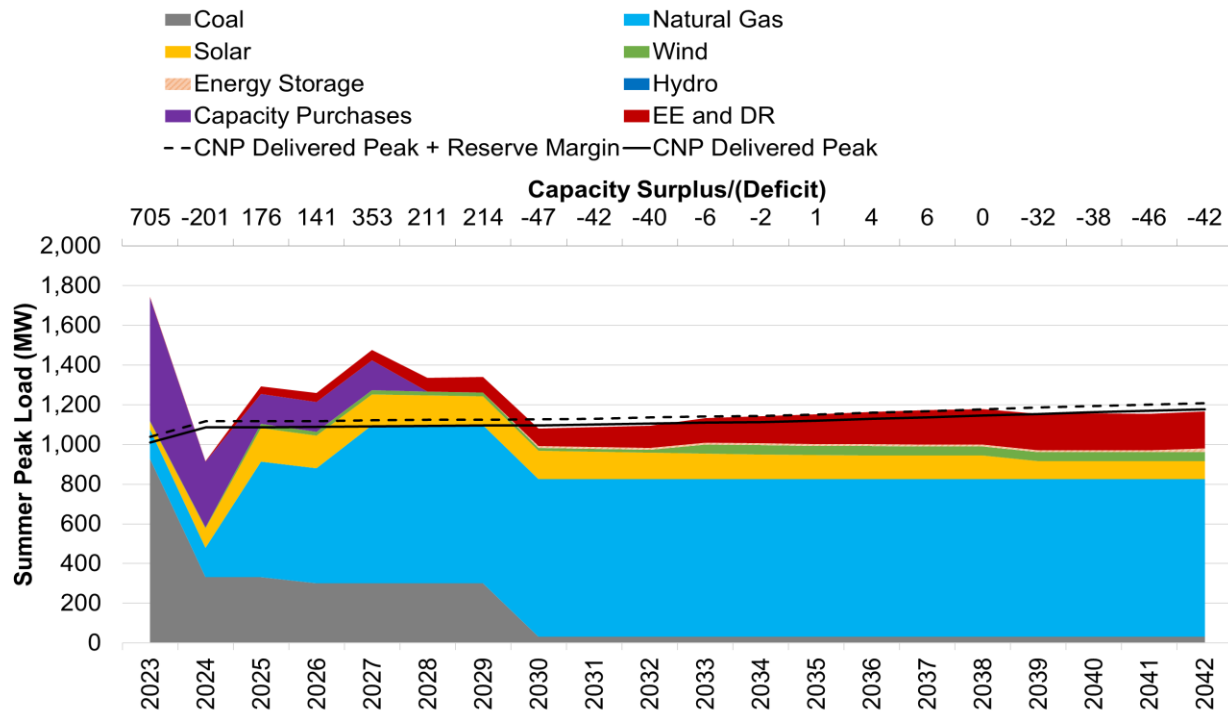
Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (20-year useful life)	Cost per ton of CO2 ($) (20-year useful Life)
ABB2	Air Heater (Steam Coil) System Repairs	2021	350	0.1	11	11,670	25.8	0	0	25.8	13.5	15.5	-2.5	19.90
ABB2	Circulating Water Pumps	2021	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
ABB2	Induced Draft Fans	2021	2,900	1.2	132.084	140,125	310.4	0	0	-2.0	-1,450.0	-1448.0	195.3	13.74
ABB2	Forced Draft Fans	2021	2,000	0.2	22	23,354	51.7	0	0	-2.0	-1,000.0	-998.0	135.3	56.86
ABB2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	3	25.3	26,840	59.5	0	0	59.5	8.4	10.4	-26.1	0.95
ABB2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.4	47	50,211	111.2	0	0	111.2	4.5	6.5	-77.9	6.61
ABB2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	66	70,018	155.1	0	0	155.1	3.2	5.2	-121.8	4.74
ABB2	Heat Rate Improvement Training	2021	15	0.3	33	35,009	77.5	0	0	77.5	0.2	2.2	-76.5	0.28
ABB2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Improved Condenser Cleaner Strategies	2021	N/A	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
ABB2	Economizer (1 Tube Pass)	2021	750	-0.17	-17.5	-18,565	-41.1	0	N/A	-41.1	-18.2	-16.2	106.0	-33.45
ABB2	Economizer (2 Tube Pass)	2021	1,075	-0.4	-37	-39,146	-86.7	0	N/A	-86.7	-12.4	-10.4	149.6	-15.80
ABB2	Economizer (3 Tube Pass)	2021	1,400	-0.61	-62.4	-66,199	-146.6	0	N/A	-146.6	-9.5	-7.5	206.9	-9.32
FBC2	Air Heater Basket, Seal, and Sector Plate Replacement	2021	476	0.5	63	12,782	28.3	0	0	28.3	16.8	18.8	3.4	5.41
FBC2	Circulating Water Pumps	2021	900	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	60.0	N/A
FBC2	Boiler Feed Pump	2021	600	0.6	76	15,337	34.0	-2	0	32.0	18.8	20.8	8.0	5.69
FBC2	Forced Draft Fans	2021	2,000	0.5	63.195	12,781	28.3	-2	0	26.3	76.0	78.0	107.0	22.74

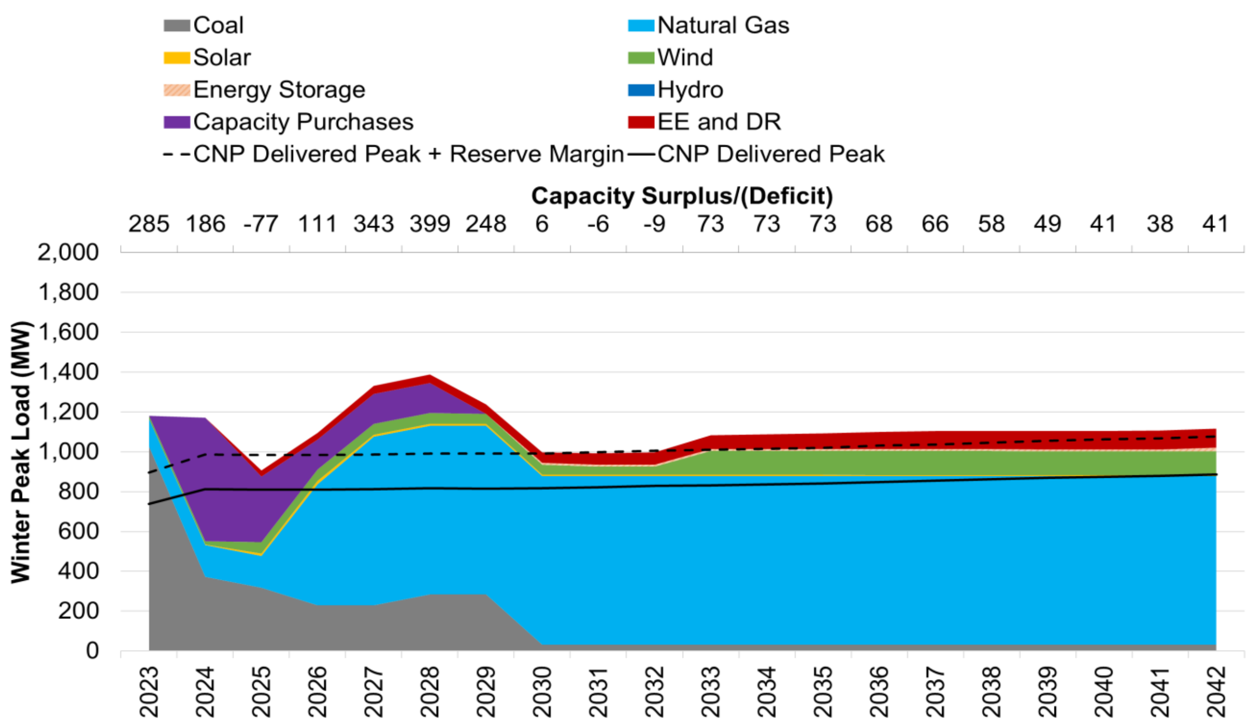
Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (20-year useful life)	Cost per ton of CO2 ($) (20-year useful Life)
FBC2	Neural Network with 0.25% Reduction in Excess O_2	2021	500	0.3	33	6,654	14.7	0	0	14.7	33.9	35.9	18.6	10.94
FBC2	Neural Network with 0.50% Reduction in Excess O_2	2021	500	0.47	59.4	12,014	26.6	0	0	26.6	18.8	20.8	6.7	6.05
FBC2	Neural Network with 0.75% Reduction in Excess O_2	2021	500	0.6	78	15,856	35.1	0	0	35.1	14.2	16.2	-1.8	4.59
FBC2	Synchronized Controlled Sootblowing System	2021	350	0.1	12.64	2,556	5.7	0	0	5.7	61.8	63.8	17.7	19.90
FBC2	Heat Rate Improvement Training	2021	15	0.3	38	7,665	17.0	0	0	17.0	0.9	2.9	-16.0	0.28
FBC2	On-Site Heat Rate Appraisals	2021	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC2	Improved Condenser Cleaner Strategies	2021	N/A	0.4	53	10,740	23.8	0	0	23.8	N/A	N/A	N/A	N/A
FBC3	HP/IP Upgrades	2022	19,900	1.5	158.3	280,580	621.5	0	0	621.5	32.0	35.0	705.1	75.44
FBC3	Air Heater Basket, Seal, and Sector Plate Replacement	2022	750	0.5	53	93,586	207.3	0	0	207.3	3.6	6.6	-157.3	8.53
FBC3	Air Heater (Steam Coil) System Repairs	2022	350	0.1	10.6	18,788	41.6	0	0	41.6	8.4	11.4	-18.3	19.90
FBC3	Circulating Water Pumps	2022	2,100	N/A	N/A	N/A	N/A	0	0	0.0	N/A	N/A	140.0	N/A
FBC3	Forced Draft Fans	2022	2,000	0.46	48.5392	86,034	190.6	-2	0	188.6	10.6	13.6	-55.2	24.72
FBC3	Neural Network with 0.25% Reduction in Excess O_2	2022	500	0.3	26	46,793	103.7	0	0	103.7	4.8	7.8	-70.3	11.37
FBC3	Neural Network with 0.50% Reduction in Excess O_2	2022	500	0.46	48.54	86,035	190.6	0	0	190.6	2.6	5.6	-157.2	6.18

Unit	Project Description	In-Service Year	Project Cost ($000's)	Heat Rate Improvement (%)	Heat Rate Improvement (Btu/kWh)	MMBtu Savings	Coal Savings per year ($000's)	Variable O&M Savings per year ($000's)	Natural Gas Savings Per Year ($000's)	Total Savings per year ($000's)	Payback Period (Yrs. from project in-service)	Total Period	Cost per year ($000's) (20-year useful life)	Cost per ton of CO2 ($) (20-year useful Life)
FBC3	Neural Network with 0.75% Reduction in Excess O_2	2022	500	0.6	65	115,919	256.8	0	0	256.8	1.9	4.9	-223.4	4.59
FBC3	Heat Rate Improvement Training	2022	15	0.3	31.7	56,187	124.5	0	0	124.5	0.1	3.1	-123.5	0.28
FBC3	On-Site Heat Rate Appraisals	2022	Variable	Variable	N/A	N/A	N/A	0	0	0.0	N/A	N/A	N/A	N/A
FBC3	Improved Condenser Cleaner Strategies	2022	N/A	0.44	46.4	82,242	182.2	0	0	182.2	N/A	N/A	N/A	N/A
FBC3	Economizer (1 Tube Pass)	2022	750	-0.1	-14	-25,169	-55.8	0	195.0	139.2	5.4	8.4	-101.7	17.53
FBC3	Economizer (2 Tube Pass)	2022	1,075	-0.28	-29.1	-51,578	-114.3	0	288.8	174.6	6.2	9.2	-120.8	23.20
FBC3	Economizer (3 Tube Pass)	2022	1,400	-0.4	-45	-79,583	-176.3	0	382.6	206.3	6.8	9.8	-136.3	29.44

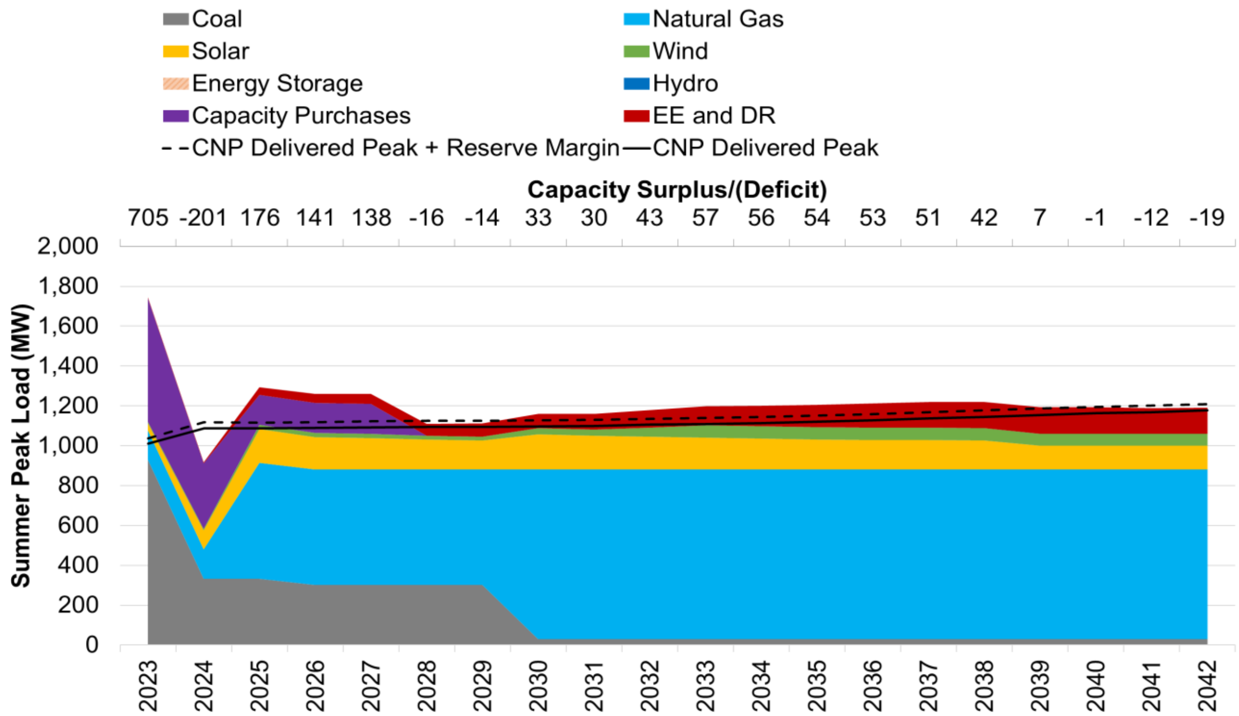
Attachment 8.1 Balance of Loads and Resources

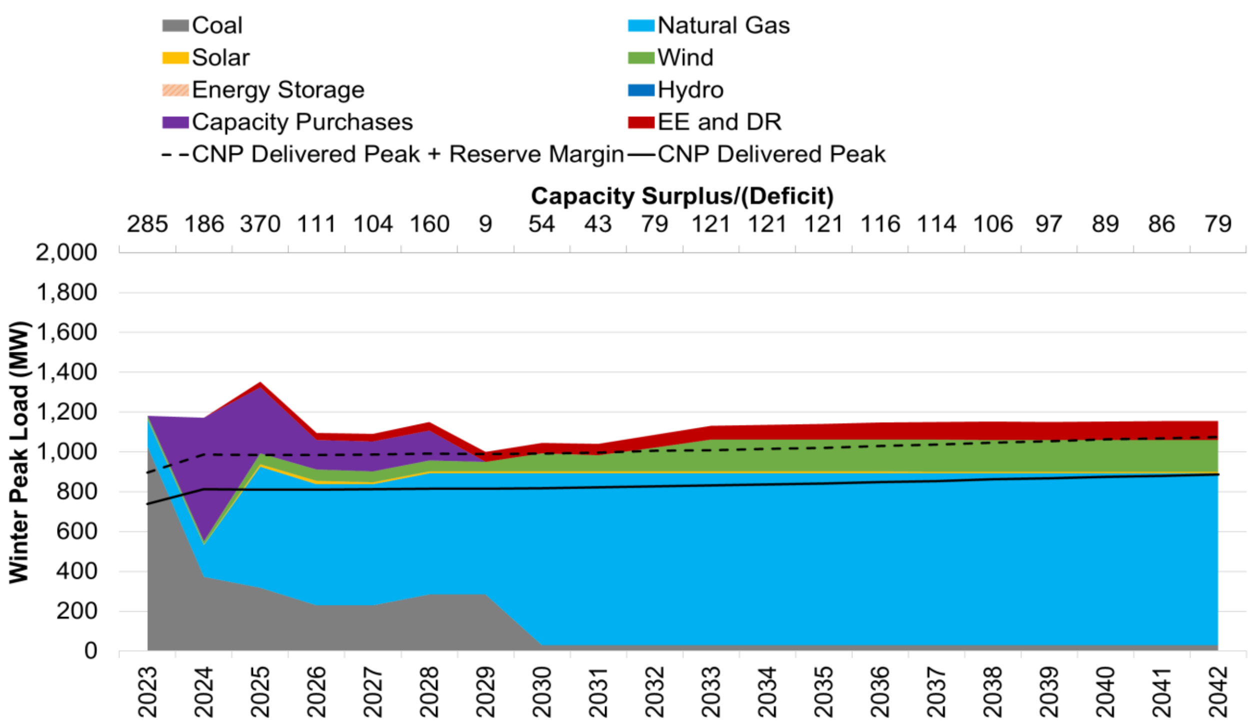
Portfolio 1: Reference Case



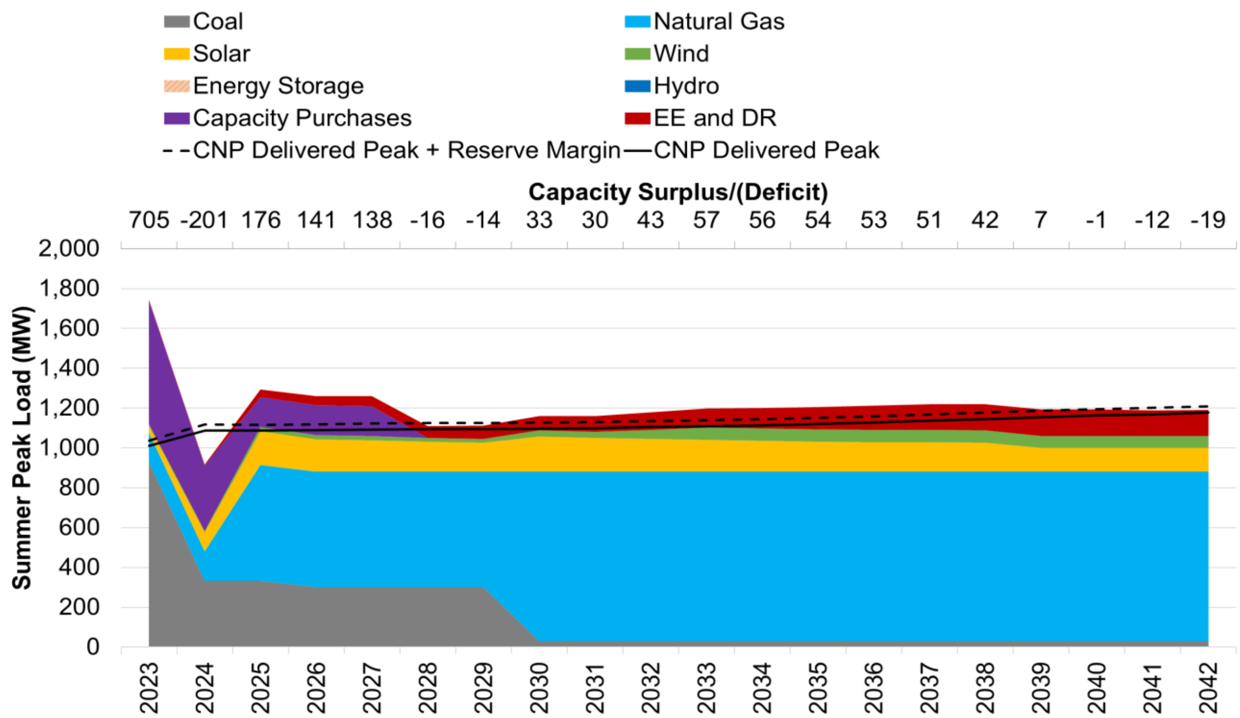


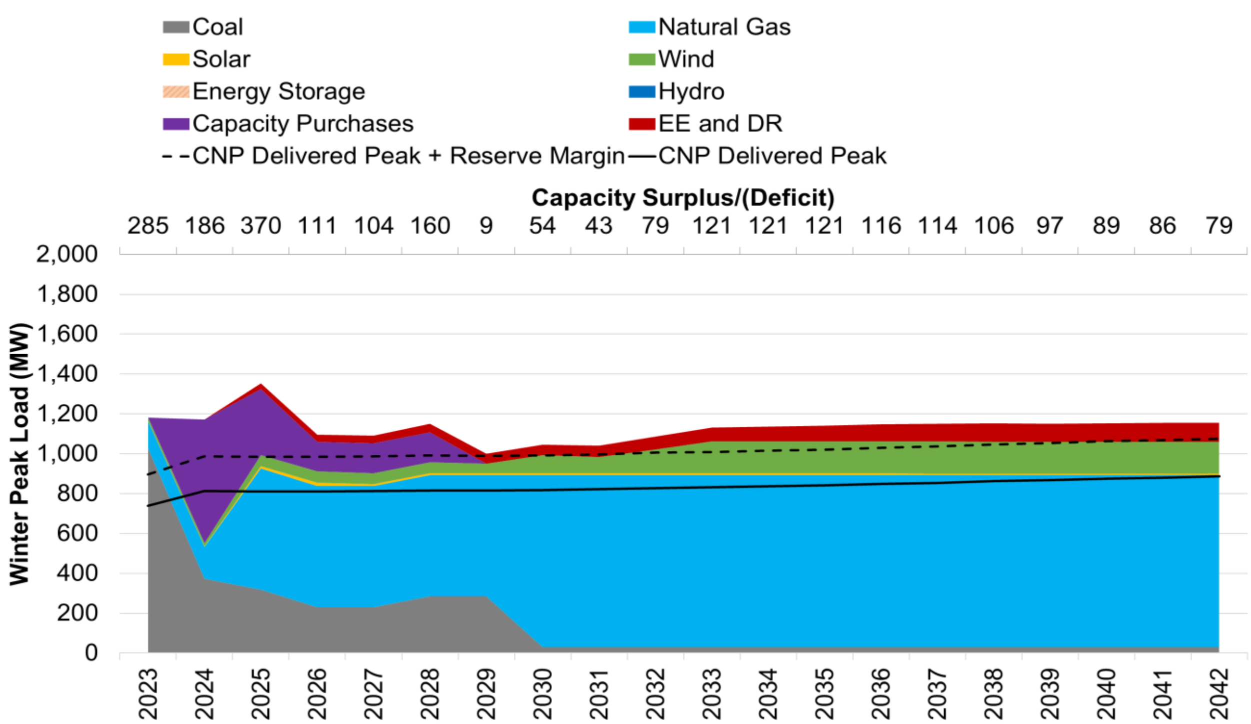
Portfolio 2: Business as Usual (BAU) Cont. FB Culley 3 on Coal



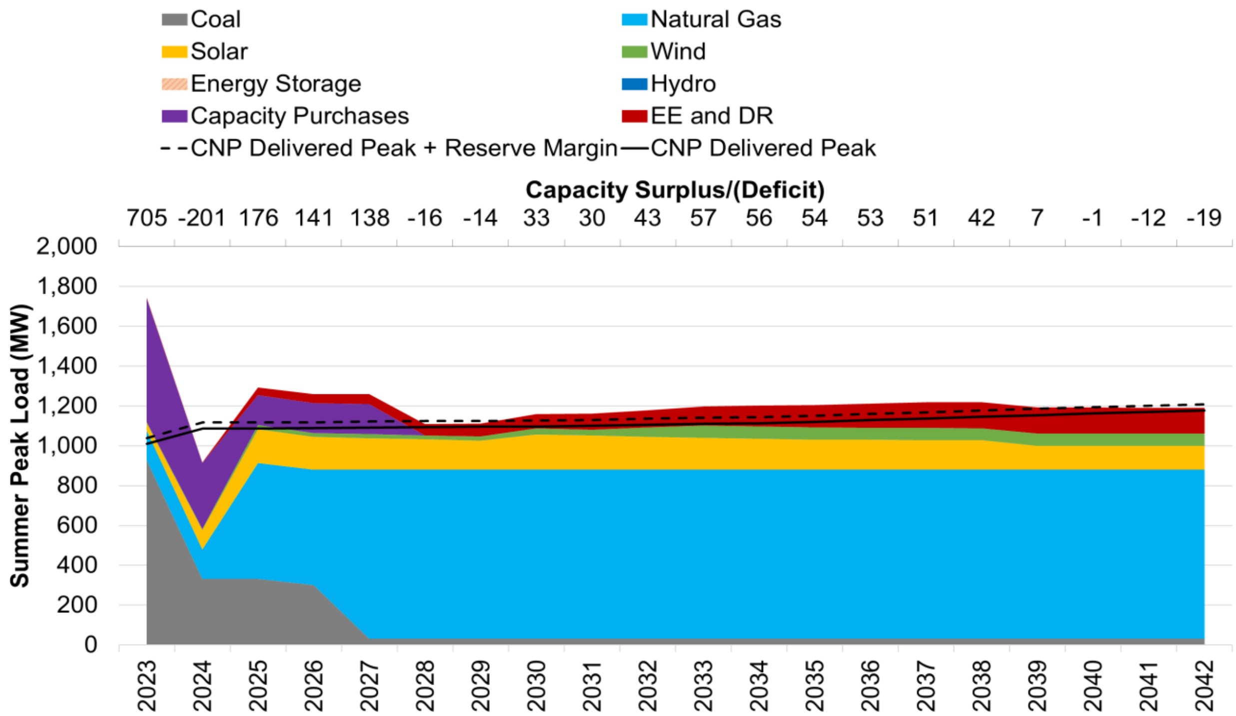


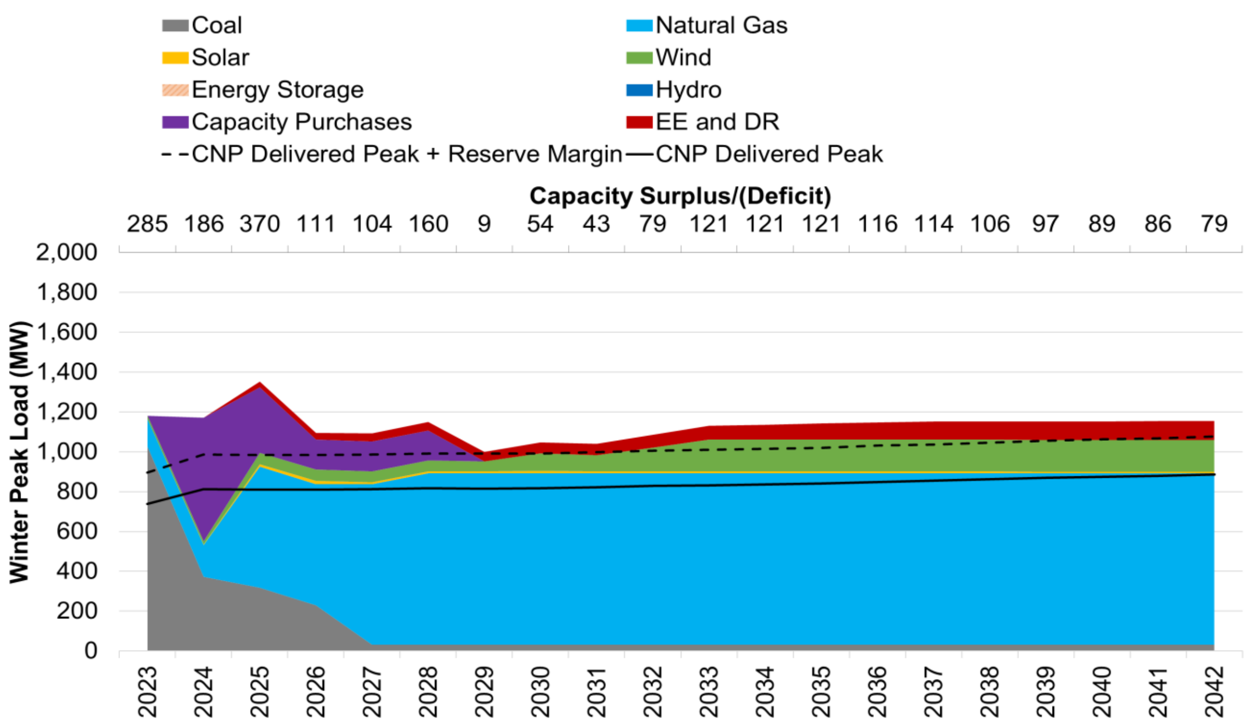
Portfolio 3: Convert F.B. Culley 3 to Natural Gas by 2030



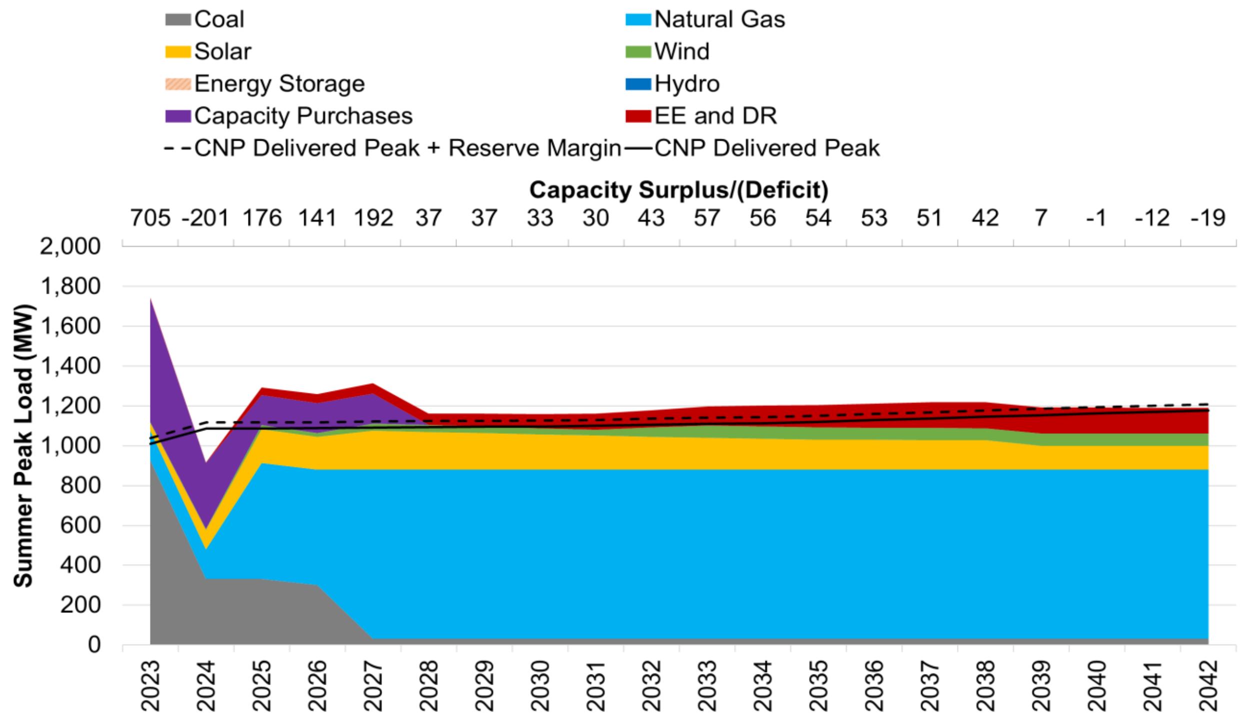


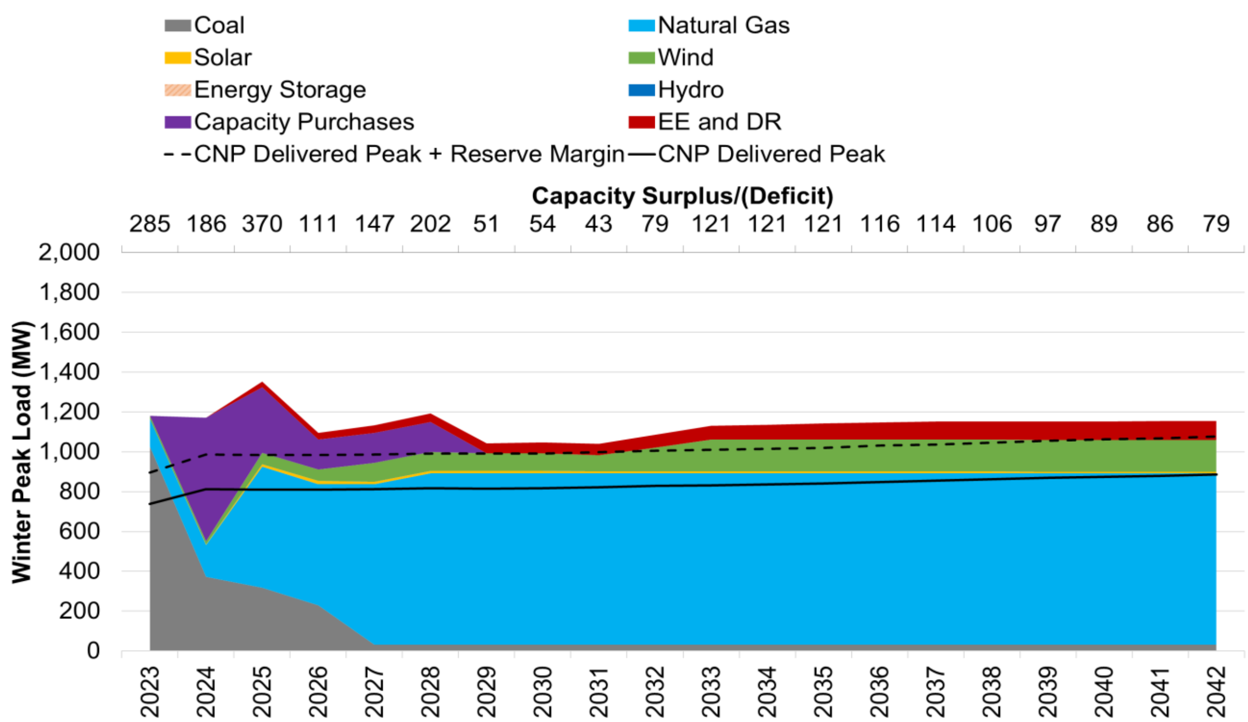
Portfolio 4: Convert F.B. Culley 3 to Natural Gas by 2027



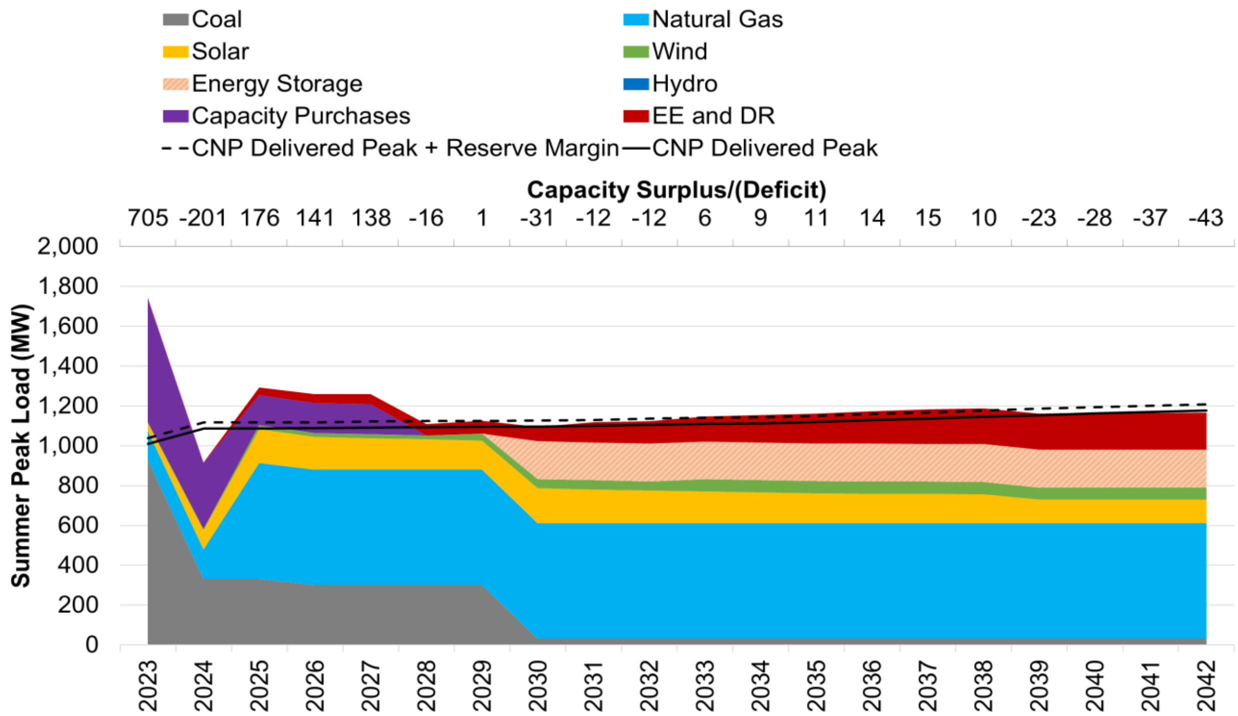


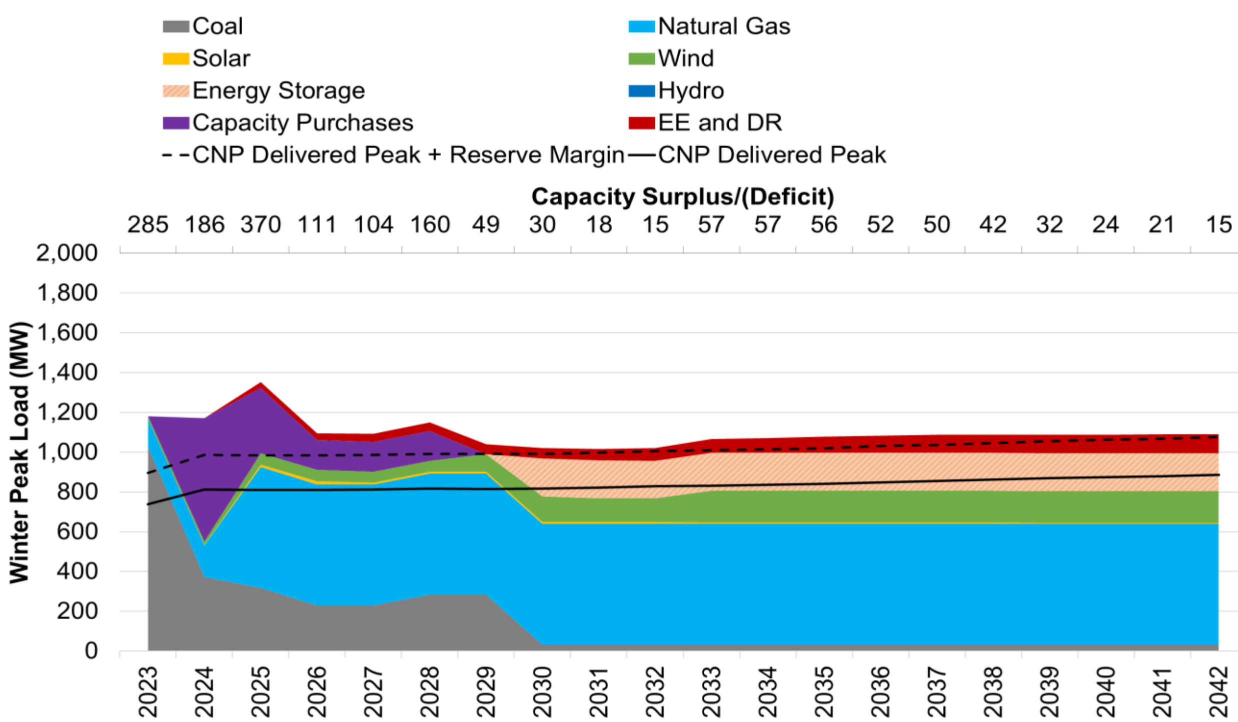
Portfolio 5: Convert F.B. Culley 3 to Natural Gas by 2027 with 2027 Wind and Solar



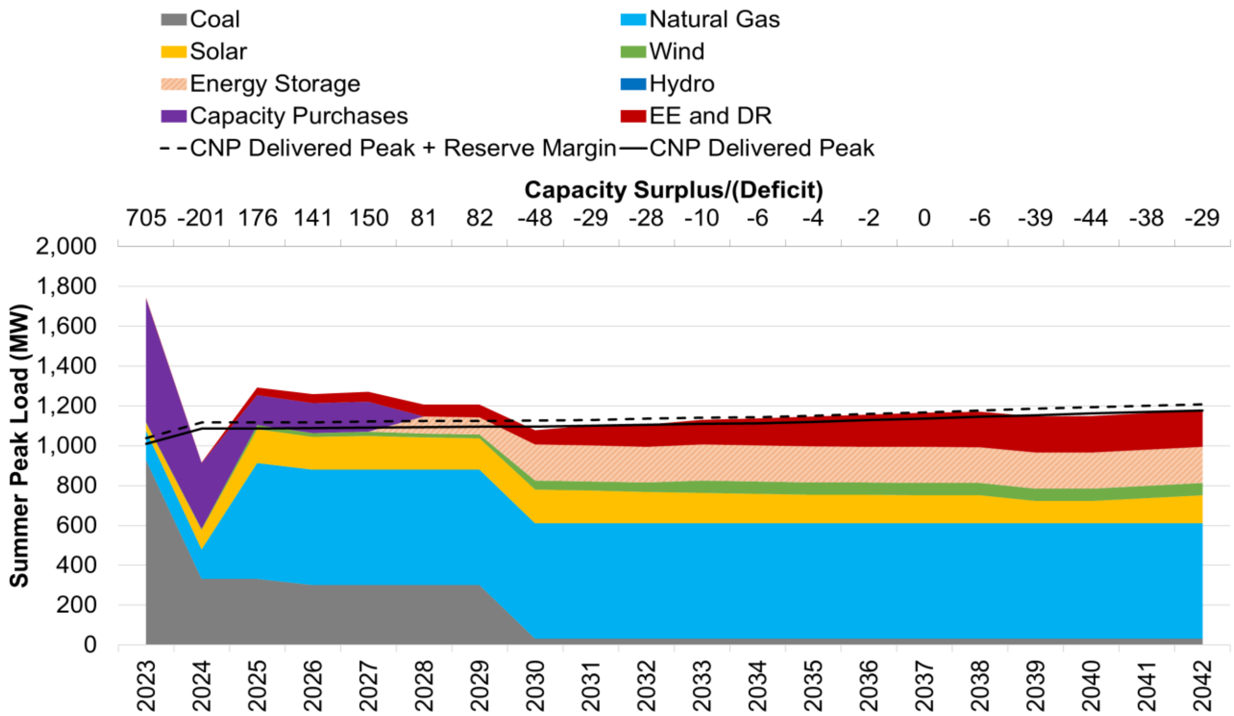


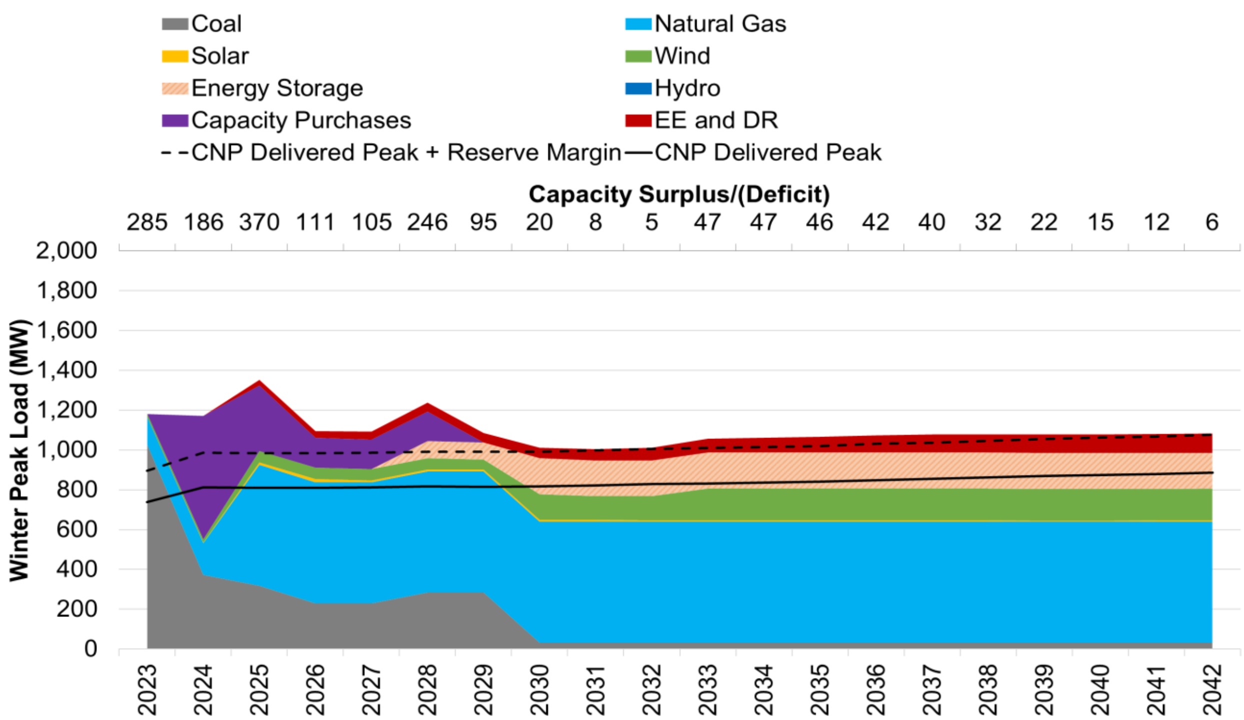
Portfolio 6: Diversified Renewables



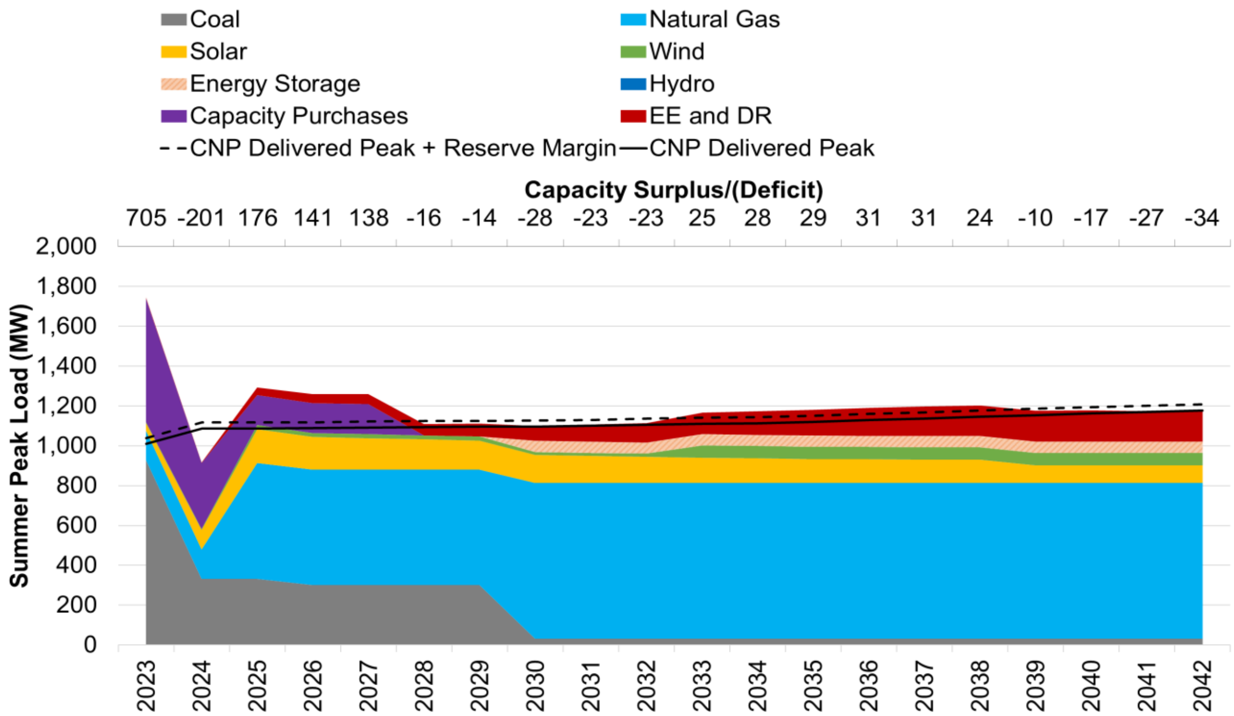


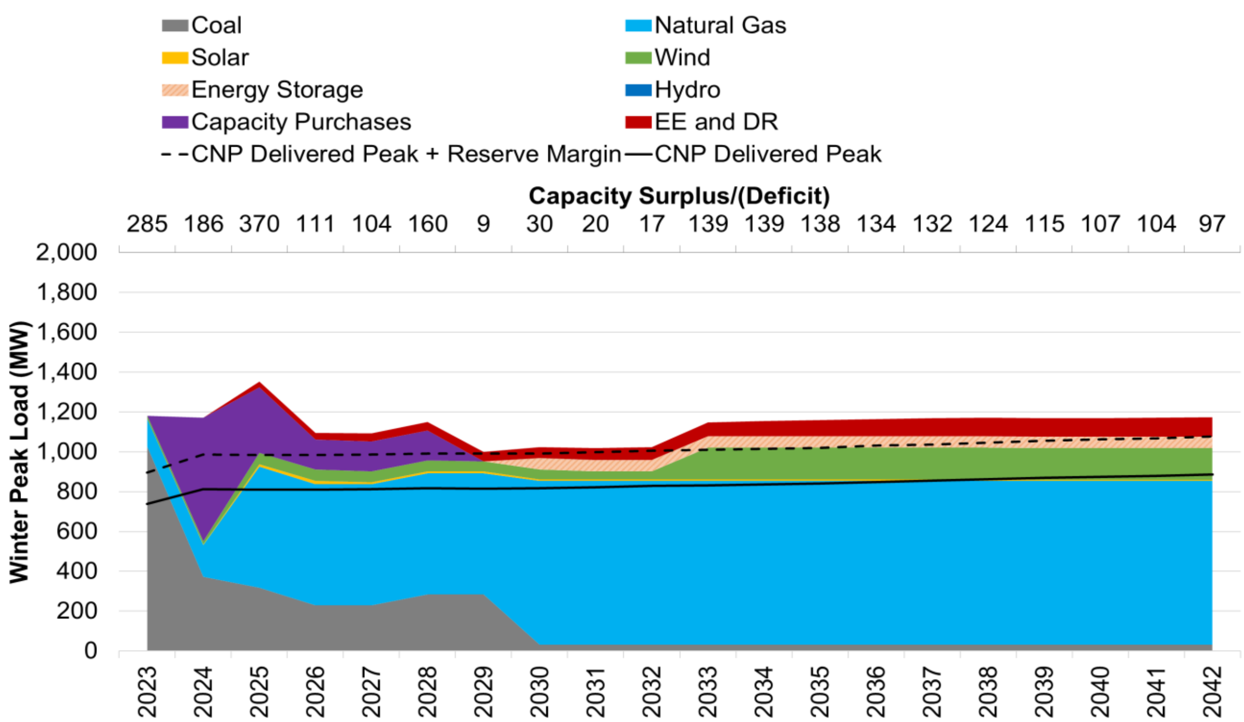
Portfolio 7: Diversified Renewables (Early Storage & DG Solar)



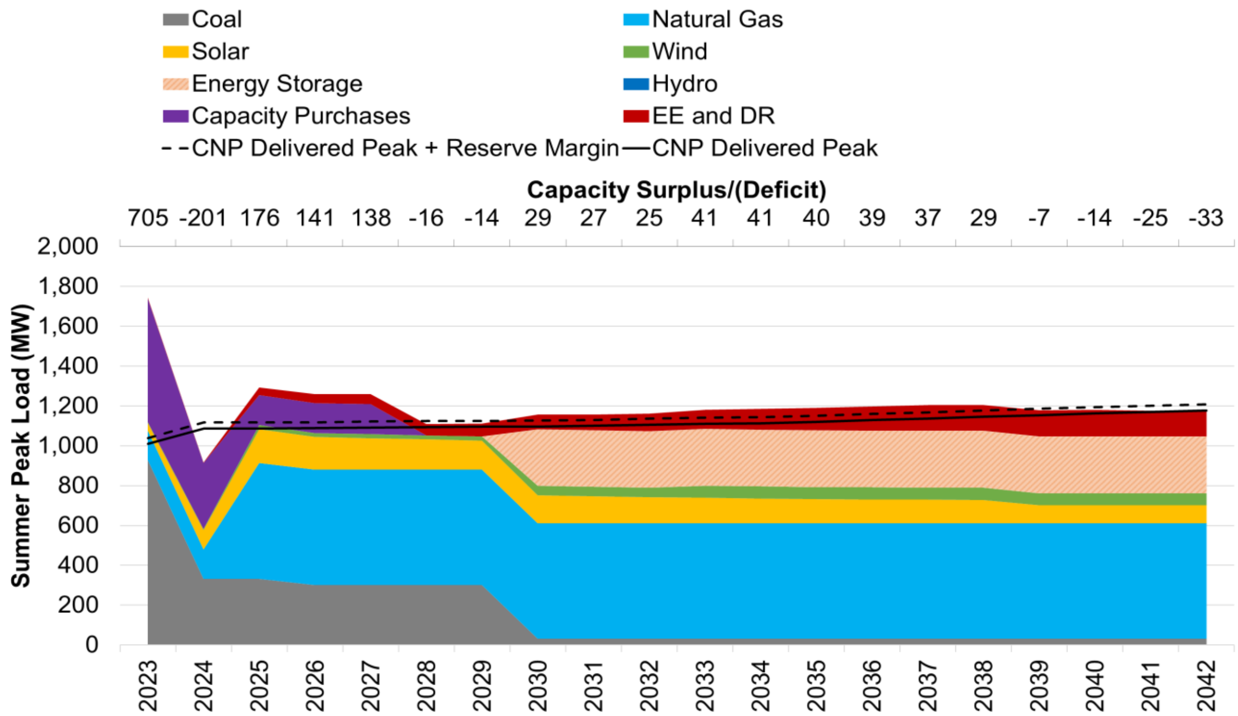


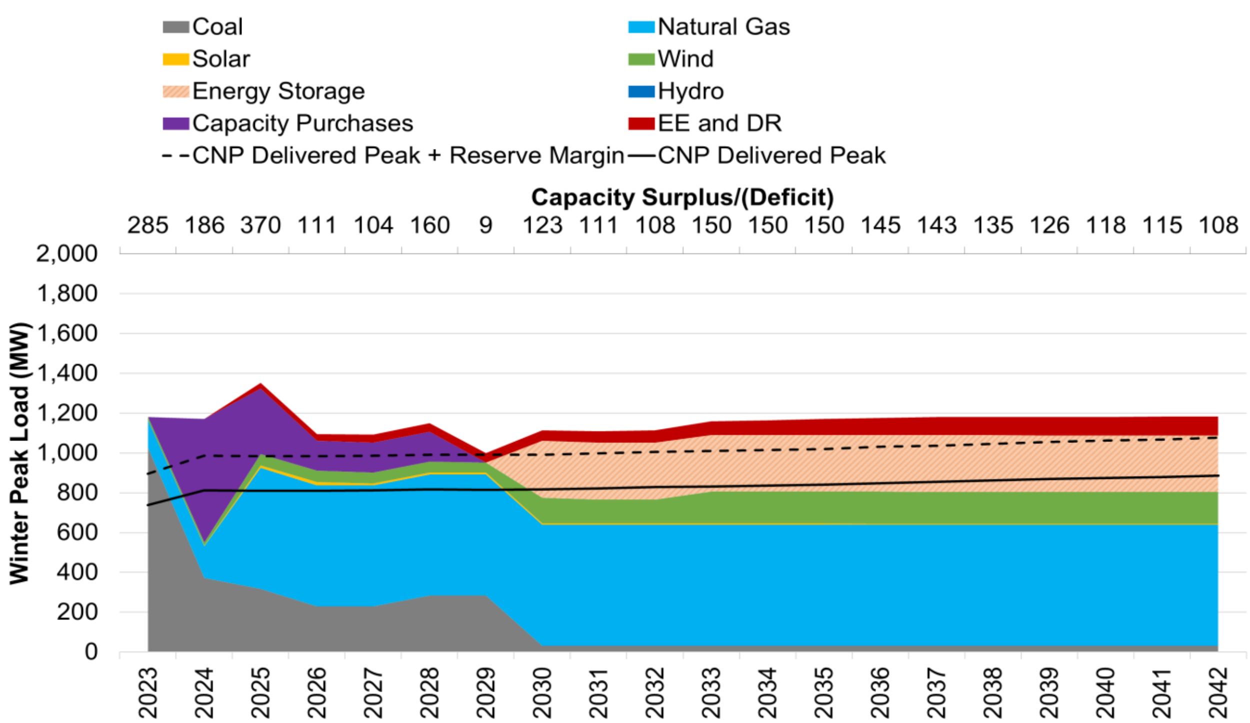
Portfolio 8: CT Portfolio (Replace FB Culley 3 with F Class CT)



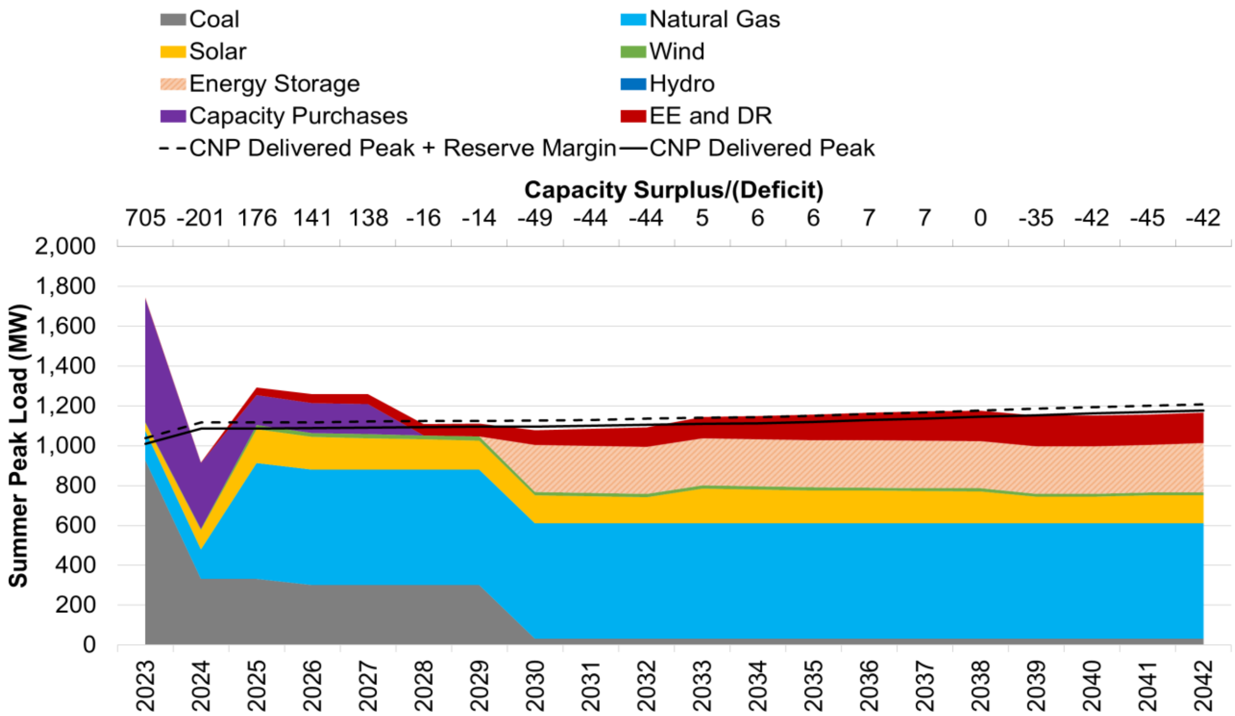


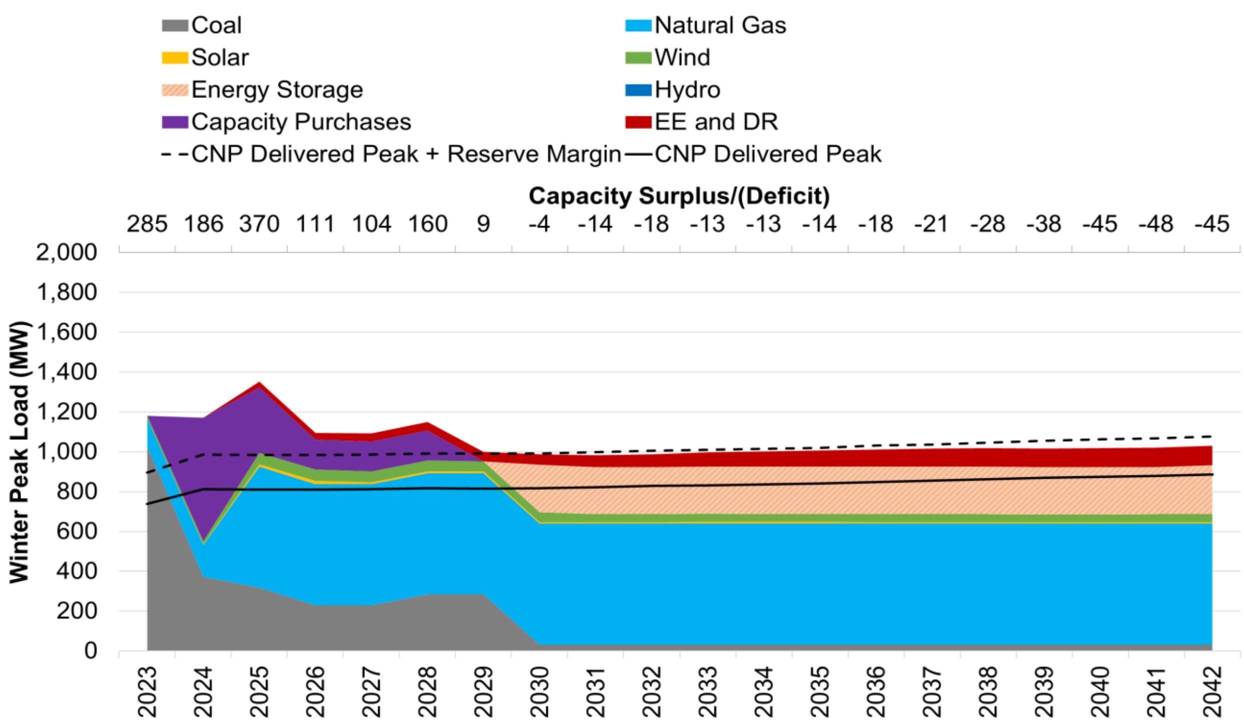
Portfolio 9: Replace FB Culley 3 with Storage and Wind





Portfolio 10: Replace FB Culley 3 with Storage and Solar





Attachment 8.2 Confidential EnCompass Input-Output Model Files

SEE ATTACHMENTS:CONFIDENTIAL - Optimized Model.zip
CONFIDENTIAL - Stochastic Model.zip