PACIFICORP ENERGY

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Fossil Fuel Heat Rate Improvement Plan

2015

Contents

Introduction

Energy Policy Act of 2005

The Energy Policy Act of 2005 amended the Public Utility Regulatory Policies Act (PURPA) of 1978. The amendments include a requirement that each electric utility develop and implement a 10-year plan to improve the efficiency of its fossil fuel generation. On August 10, 2007, The Utah Public Service Commission determined that it was in the public interest to adopt the PURPA Fossil Fuel Generation Efficiency Standard.

This standard reads as follows; **each electric utility shall develop and implement a 10 year plan to increase the efficiency of its fossil fuel generation.**

The implementation of this standard requires PacifiCorp Energy to annually file information related to the fleet heat rate efficiency and develop a plan to improve generation efficiency.

Per agreement with the Utah Public Services Commission, the fossil fuel fleet will include the owned and operated coal fired plants and gas fired combined cycle plants

Integrated Resource Plan (IRP)

The integrated resource plan (IRP) is a comprehensive decision support tool and road map for meeting the company's objective of providing reliable and least-cost electric service to all of our customers while addressing the substantial risks and uncertainties inherent in the electric utility business. The IRP is developed with considerable public involvement from state utility commission staff, state agencies, customer and industry advocacy groups, project developers, and other stakeholders.

The key elements of the 2015 IRP include the following;

1. A finding of resource need, focusing on the 10-year period 2015-2024,
2. The preferred portfolio of incremental supply-side and demand-side resources to meet this need. (Ref Appendix A)
3. An action plan that identifies the steps the Company will take during the next two to four years to implement the plan.

The IRP uses system modeling tools as part of its analytical framework to determine the long-run economic and operational performance of alternative resource portfolios. These models simulate the integration of new resource alternatives with our existing assets, thereby identifying a preferred portfolio judged to be the most cost-effective resource mix after considering risk, supply reliability, uncertainty, and government energy resource policies.

PacifiCorp continues to evaluate energy efficiency as a resource that competes with traditional supply-side resource alternatives when developing resource portfolios that are compared under a range of cost and risk metrics. The IRP includes core case resource portfolios developed assuming accelerated acquisition of energy efficiency resources. While the assumptions developed for these cases may require further validation and review, cost and risk analysis of these portfolios have led to action items to accelerate acquisition of cost-effective energy efficiency resources.

Summary

Improving the fleet efficiency of PacifiCorp's fossil fuel generation is embedded in the Company's bi-annual IRP, as currently implemented under the rules and standards within the States served. Fossil fuel generation efficiency is typically reported using average heat rate, measured in British Thermal Units (BTU) per kilowatt hour (kWh). The efficiency of a generating unit is improved when the heat rate is decreased. The efficiency of the Company's fleet of fossil fuel generation is improved when the weighted average heat rate of the fleet is decreased.

Fossil fuel generation fleet efficiency can be improved by the following three main activities;

1. Maintaining an emphasis on the continuous improvement of existing generating fleet efficiency
2. Adding new fossil fuel generation with improved efficiency
3. Retiring old and less efficient fossil units

For the purposes of this report, the Company's fleet is defined as coal fired units and gas fired combined cycle plants owned and operated by PacifiCorp Energy.

This report will describe the key items that specifically support the Company's on-going heat rate management and improvement process as it applies to the fossil fuel generation fleet. Charts and tables based on publically available data will be presented that indicate an on-going improvement in the fleet weighted average heat rate over the last 10 years. Charts and tables based on forecasted data will indicate on-going heat rate improvement over the next 10 years.

Power Plant Cycles

The energy conversion process in a thermal power plant begins with some form of chemical energy (e.g. coal, oil, gas), then ultimately converts the chemical energy to electrical energy. Two of the most common thermal power plant types are conventional fossil plants and combined cycle plants.

The Steam-Water (Rankine) Cycle

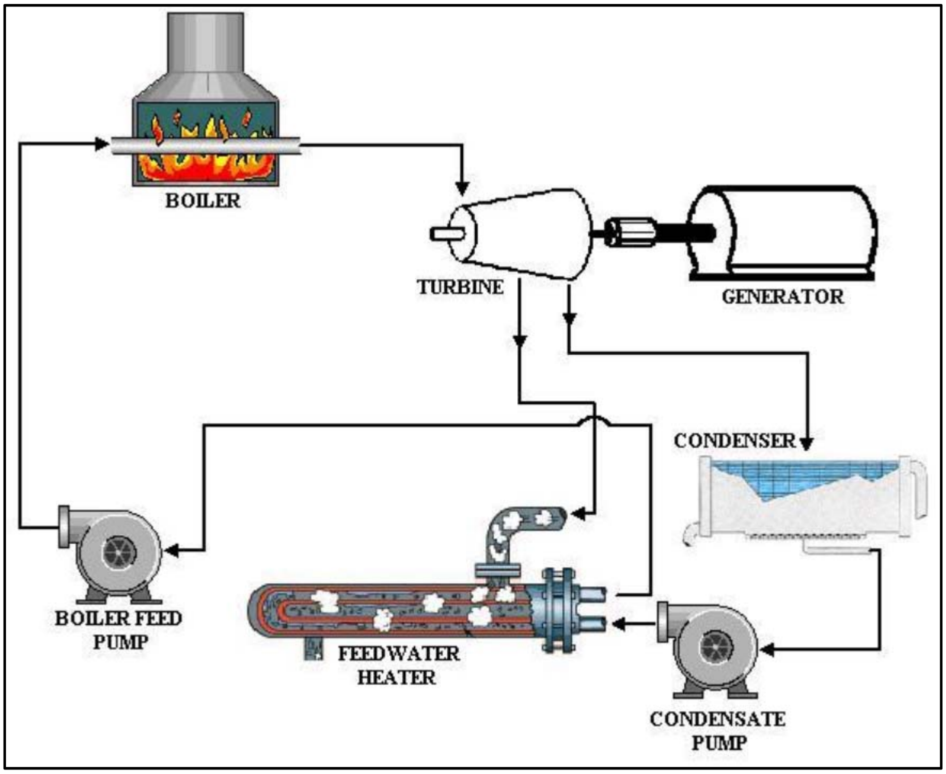
A conventional power plant utilizing the Rankine cycle consists of the following systems: boiler, turbine, cooling, and condensate/feedwater.

In a conventional fossil power plant, the process follows these steps:

- Combustion converts the chemical energy to heat
- Part of the heat is transferred to the working fluid (water or steam)
- Part of the heat is lost with the heated flue gas
- Part of the steam energy is transferred to the turbine
- The turbine converts the energy in the steam to mechanical energy
- Mechanical energy drives a generator, converting mechanical to electrical energy
- A large part of the steam energy is lost as exhaust steam is condensed and heat energy transferred to the condenser circulating water as waste heat.

The goal of combustion is to get as much heat transfer to the boiler while at the same time minimizing heat losses. These heat losses can occur through flue gas, incomplete combustion (unburned carbon) and radiation. On the turbine side the goal is to maximize the amount of energy being pulled from the steam while minimizing the use of auxiliary power and other losses, such as leaks, missing insulation, etc.

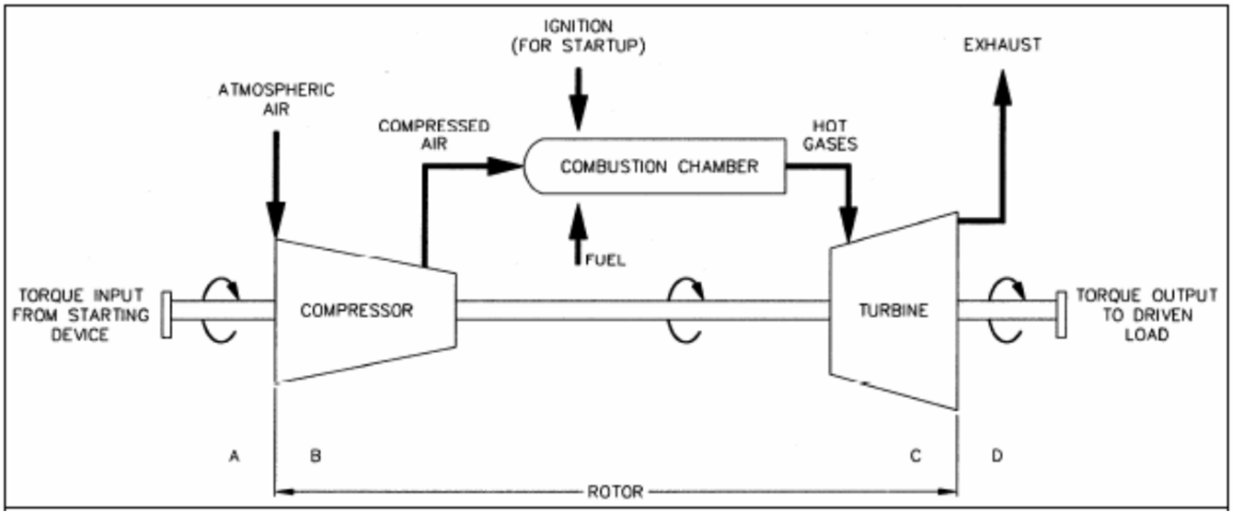
A steam power plant is based on the regenerative Rankine cycle. The figure below depicts a simple single-extraction regenerative Rankine cycle.



Single Extraction Regenerative Rankine Cycle

The Combustion Turbine (Brayton) Cycle

The basic combustion turbine consists of a compressor, a combustion section, and a turbine section. Air is drawn into the compressor which raises the air pressure by a factor of 12 to 18:1. The temperature of the air also increases with compression, and may be as high as 600F (316°C) at the compressor discharge.

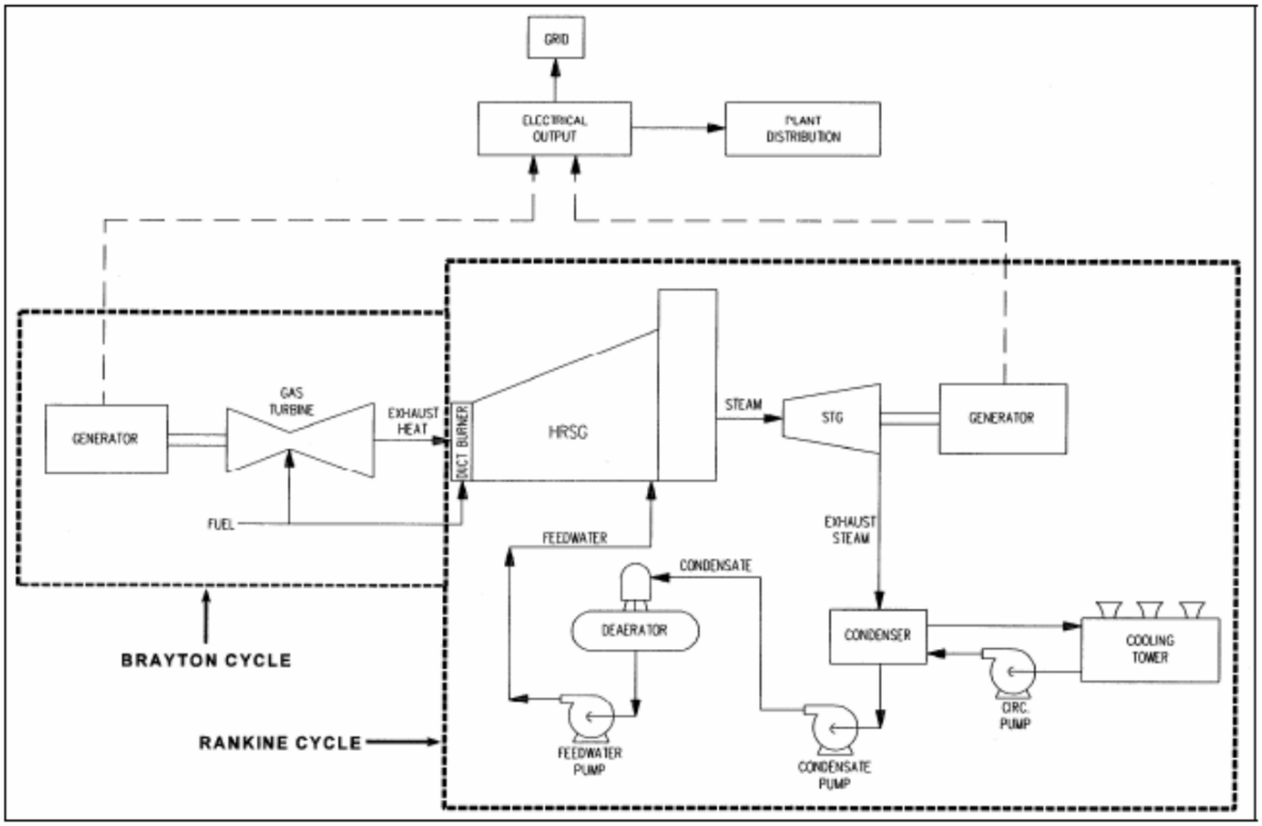


Simple Cycle Combustion Turbine Configuration

In the combustion section, fuel is injected into the compressed air and burned to convert the fuel's chemical energy into heat energy. The amount of energy contained in the gas is directly proportional to the amount of heat energy, thus the resultant horsepower generated by the turbine. Firing the fuel in the combustor results in a high temperature, high pressure exhaust gas with considerable thermal energy. This hot gas enters the turbine section where it expands, giving up its thermal energy to the blades of the rotating turbine. In the process of expanding and cooling through the turbine section, the thermal energy of the gas is converted into mechanical energy that is used to do work. A large portion of the work from the turbine, about 60-67%, is used to drive the compressor. The remainder of the turbine work is available to produce power by driving a generator. The heat exhausted from the combustion turbine is typically in the range of 900 to 1100°F (482-973°C).

The Combined Cycle

Combined cycle refers to a power plant in which a combustion turbine is integrated with a Rankine Cycle. The Rankine Cycle makes use of much of the heat in the combustion turbine exhaust gases. Thermodynamically, the combined cycle can be represented by joining the high temperature Brayton cycle with the moderate pressure and temperature Rankine Cycle. An example of a combined cycle showing the Brayton cycle (combustion turbine) and the Rankine Cycle (steam turbine) is shown in the Figure below.



Combined Cycle Power Plant

Factors Effecting Optimum Heat Rate

System Losses due to Equipment Degradation

A power plant is a collection of individual components or systems that combine to convert chemical energy into electricity. The systems are designed to operate together, but each can be studied individually. In general terms, the efficiency of any system in a power plant is a ratio of the useful energy output by a system to the energy input to the system. This yields the following general equation for efficiency:

Efficiency = Useful Energy Output/ Energy Input

The useful energy output and the energy input can be defined in a number of different ways for different types of components or systems, however, for all systems, increasing efficiency results in reduced cost.

Within these described systems there are many areas where losses will occur due to equipment degradation. The following is a partial list of some of the more common losses along with a brief explanation

1. **Steam Turbine**

a. Deposition: Turbine deposits result from impurities in the boiler water being carried over into the steam turbine. Deposits have two primary effects on turbine performance. First, the deposits reduce the flow area in the turbine blades, which reduces flow through the turbine. This reduces the generating capacity of the unit and usually causes a decrease in efficiency. The second effect is an increase in surface roughness, which has a significant, negative impact on turbine stage efficiency.
b. Solid Particle Erosion: Solid particle erosion occurs when the oxide scale formed in the boiler exfoliates (flakes off) and is carried by the steam to the turbine. This is usually a problem in the first stages of the high pressure and intermediate pressure turbines and is more pronounced on cycling units.
c. Mechanical Damage: Mechanical damage to the steam path is considered any alteration of the turbine steam path from design other than that caused by deposits or erosion.
d. Internal Seal Leakage: Internal leakage includes any shaft packing leakage, radial spill strip leakage, casing leakage, snout ring leakage, or any other leakage that allows steam to travel within the turbine shell around or bypassing the intended steam path.
e. Cycle Isolation: Steam power plants have a design flow path for all of the water or steam that enters the system. When flow is diverted from the normal steam path it can be lost from the cycle completely or returned to a section of the cycle where the energy is detrimental to unit performance.
f. Non-Recoverable Losses: Due to the on-going wear within the steam turbine sections, some degradation is non-recoverable. These losses have been documented in the 2-3% range across the industry.

2. **Boiler**
   a. Dry Gas Losses: The quantity and the temperature of the flue gas determine the total heat that exits the stack. The quantity of gas is dependent on the fuel being burned, but is also influenced by the amount of excess air supplied to the burners. While sufficient air must be provided to complete the combustion process, excessive quantities of air simply carry extra heat out of the stack.
   b. Excess O2 (oxygen): High excess air tends to increase the exit gas temperature and draft losses, and demands adjustments to the fuel/air ratio.
   c. Fuel Properties: Each fossil boiler is designed to burn fuel within a specific quality range known as “design fuel”. Fuel heat content variations can have a significant impact on unit performance.
   d. Air Heater Seal Leakage: Air heater leakage affects unit performance in two ways. First, it requires the operator to maintain boiler exit temperatures higher than normal to compensate for the cooling effect of the air leakage or it requires the use of energy using devices such as steam coils, glycol heaters, or hot air recirculation to raise the incoming combustion air temperature. Second, it places an additional duty upon the induced draft fans in a balanced draft furnace which may result in total air flow capacity limitations.

e. Boiler Tube Surface Fouling: Fouling of the boiler tubes on either side of the tube decreases heat transfer and typically causes a decrease in boiler efficiency. Fouling on the inside of the tubes is usually called scaling or deposition.
f. Casing Leakage: On a balanced draft furnace, air in-leakage can occur at any location where the furnace pressure is less than atmospheric pressure. There are two primary effects of boiler casing in-leakage. In the first instance, air leaks in at ambient temperature, is heated in the boiler, and is carried out the stack. The second problem with air in-leakage is that most units measure boiler O2 at the economizer exit. If there is casing in-leakage after the furnace and before the economizer exit, the economizer O2 measurements will indicate a higher oxygen concentration in the flue gas than is appropriate for complete combustion.

3. Condenser

a. Condenser Pressure: Efficiency increases as condenser absolute pressure decreases. With condenser pressure as low as possible the amount of heat rejected is lower and the amount of work produced by the turbine increases, since the enthalpy drop across the turbine becomes greater. Increased condenser pressure will reduce efficiency.
b. Cooling Water Inlet Temperature: High circulating water inlet temperature has a significant effect on unit performance. An increase in temperature will reduce condenser performance by increasing the condenser pressure.
c. Heat Load: An increase in the heat load on the condenser will increase the condenser pressure. During normal operation, the increase in heat load would normally be a result of an increase in unit load. If the heat load increases for other reasons, then the condenser pressure increases and unit performance suffers.
d. Circulating Water Flow: Low circulating water flow through the condenser tubes results in an increase in the average circulating water temperature. Since a decrease in flow results in a decrease in water velocity through the tubes, the water has more "residence time" in the tubes, absorbs more heat, and therefore increases the average water temperature.
e. Tube Fouling: The cleanliness of the tubes in the condenser has a significant impact on the condenser's ability to transfer heat from the exhaust steam to the circulating water. If the circulating water flow through the condenser is normal and the terminal temperature difference is high, it is likely that the heat transfer is impaired due to fouling or scaling.
f. Condenser air-in Leakage: Air in-leakage can occur through gland seals or through leakage in the piping and components under vacuum. The effect of air in-leakage on the condenser is that the pressure increases and unit efficiency decreases.

4. Feedwater Heaters

a. Feedwater Heater Out of Service: Operating a unit with one or more feedwater heaters out of service will have a significant impact on the performance of the turbine, the boiler and other plant auxiliaries. From a heat rate standpoint, removing a heater from service will almost always increase heat rate. Feedwater Heater Degradation: When tube leaks develop in feedwater heaters, the tubes are plugged. Plugging the tubes reduces the heat transfer area of the feedwater heaters; however, most feedwater heaters are designed with approximately 10 percent excess heat transfer surface above design requirements.

System Losses due to Controllable Losses

Controllable losses, often called operator controllable losses, are defined as those heat rate losses that can be directly impacted (either positively or negatively) by the actions of the unit control operator. In many cases, the actual "control" is handled by the control system, but often, operator intervention can impact the magnitude of the loss.

In a conventional fossil power plant, the following areas may be considered controllable losses:

- Steam condition parameters including temperature and pressure
- Spray flows for the superheater and reheater sections
- Economizer O2 and exit gas temperature of the boiler
- Condenser pressure
- Final feedwater temperature
- Auxiliary steam and power

Below is a listing of the controllable losses.

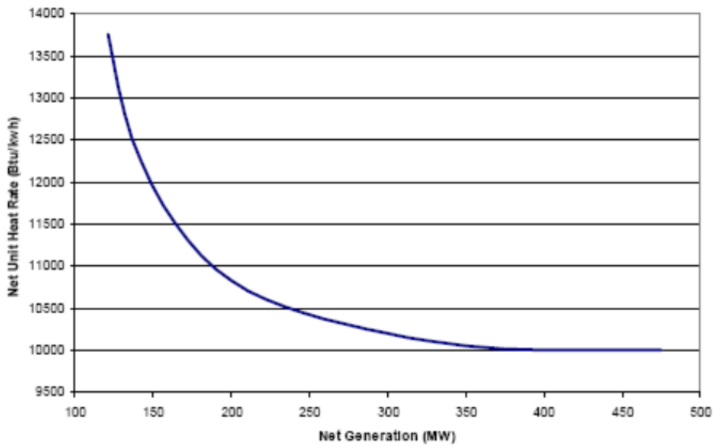
1. Main Steam Pressure: The primary effect of off design main steam pressure is not directly a heat rate effect, but more of a capacity effect. Higher main steam pressure increases the density of the steam entering the turbine, so that more steam flow can pass through the turbine at a fixed valve position.
2. Main Steam Temperature: Main steam temperature is one of the most important of the operator controllable parameters relating to heat rate. The design main steam temperature at the turbine for most modern generating units is 1000ºF (537.8ºC). Increasing the main steam temperature increases the energy available to the turbine.
3. Hot Reheat Temperature: Hot reheat temperature has a significant effect on both heat rate and generation. As with main steam temperature, a higher temperature yields higher steam enthalpy and more energy available to the turbine. Because the intermediate pressure and low-pressure sections produce about 70 percent of the power, this change in available energy has a significant impact.
4. Superheat and Reheat Spray Flows: Attemperation sprays are used for temperature control in a boiler. The sprays are usually controlled to yield either an intermediate temperature (intermediate superheater outlet temperature) or a final boiler temperature (main steam or hot reheat). Reheat and superheat spray flows have distinctly different effects on unit performance, but in general, both increase heat rate and unit output.
5. Excess O2: During the combustion process, the oxygen in the combustion air mixes with the combustibles in the fuel, primarily carbon, to release heat into the furnace. In theory, the combustion process requires an exact amount of oxygen to fully combust all of the carbon in the fuel. In the real world, an additional amount of oxygen is supplied so

that as much of the carbon as possible is combusted. This additional amount of oxygen is called “excess air”.

6. Exit Gas Temperature: The boiler exit gas temperature is considered the boundary of the boiler, or the last location where a benefit is derived from the hot flue gas. For most boilers, this point is at the air heater outlet. Maintaining the proper exit gas temperature is a delicate balancing act. On one hand, the lower the gas temperature can be maintained the better the boiler efficiency. On the other hand, problems result when the exit gas temperature is low enough to approach the acid dew point temperature.
7. Condenser Pressure: Condenser pressure has the single largest effect on unit performance of any single parameter. A change in condenser pressure causes a change in the enthalpy of the steam at the condenser, which affects the overall usable energy in the turbine cycle. In general, an increase in condenser pressure reduces turbine efficiency and output, and a decrease in condenser pressure improves turbine efficiency and output.
8. Final Feedwater Temperature: From the boiler standpoint, lower feedwater temperature to the economizer requires additional fuel to raise the water temperature in the boiler to the saturation point. If the temperature is low enough, the boiler has to be over fired to achieve the required temperature at the water wall exit.
9. Auxiliary Steam Flow: Most units are configured to supply auxiliary steam from the boiler, either from the drum or the primary superheat section, for startup and low load operation. As the unit load increases, the steam supply usually switches to the turbine crossover or a low-pressure turbine extraction. If steam is supplied from the boiler instead of the turbine, unit load will increase, but heat rate will also increase significantly. Auxiliary steam flow from a lower pressure location in the turbine train is typically more efficient than extracting steam from the higher pressure boiler area; allowing the higher pressure steam to perform work in the turbine prior to extracting required steam flow from a lower pressure section of the turbine cycle nearer required supply conditions.
10. Auxiliary Power: Auxiliary power affects the amount of electricity that is available at the switchyard for sale. Increases in auxiliary power consumption increases net unit heat rate and net turbine heat rate based on full load operation. As load decreases, one megawatt is a larger percentage of total power and results in a much more significant impact on heat rate.

Dispatch

Heat rate vs load curves are produced based on data from performance heat rate tests conducted over the load range of the unit. These curves tend to be utilized by both the plant and dispatch personnel to know what the heat rate is for a particular unit at a particular load. The figure below is a typical heat rate vs load curve. As shown, heat rate normally increases at lower loads. Therefore if a unit is dispatched to a lower load due to any system condition, then unit efficiency will decrease.



Typical Heat Rate vs Load Curve

Unit dispatch based on incremental generation costs and incremental heat rate along with other factors is further discussed in the Dispatch Philosophy section.

Heat Rate Management Process Summary

Economics naturally drive the Company to improve the fuel efficiency of the existing fossil fuel fleet. Fossil fuel is the Company's single largest expense. PacifiCorp is committed to maximizing fleet generating efficiency.

Heat rate or thermal efficiency of the thermal generating units is affected by many factors including fuel quality, unit original design, load profile, unit operation, unit maintenance, weather, system conditions, and economics. All of these factors change over time. Some of these factors change minute by minute. Some of the factors are out of the control of PacifiCorp personnel. The overall objective of heat rate management is to continuously maintain the best possible unit heat rates given these changing factors.

Heat rate management and improvement is based on the following key principles and concepts:

- The Company maintains an emphasis on operating as near optimum efficiency as practical given fuel quality and maintenance schedules. Control software has been installed to help operators assess the efficiency impact of sub optimal operation on a real time basis. Monthly reports are prepared to track the fleet efficiency relative to budget.
- Units that are not dispatched at maximum output should always be operated in a manner that results in the lowest heat rate. Units that are dispatched at full load are operated in a manner that maximizes generator output and produces the best achievable heat rate at full load conditions.
- The load profile of each unit is dictated by the economic dispatch of the generating units to meet the system load demand.
- Unit and equipment performance is monitored on a continuous basis where practical. Periodic testing is performed on key equipment that is not monitored continuously.
- The Company considers design upgrades to existing units when they become available through improved technology. Improvements are evaluated taking into consideration

impact on efficiency, availability and cost of operation. Economically justified improvements are incorporated into the capital budget and unit overhaul plans.

- Consistent and uniform heat rate reporting is essential for budgeting and regulatory requirements and is coordinated at the corporate level.
- Good feedback on unit heat rate and equipment performance is essential for plant personnel to control and manage heat rate. Personnel will take action if they recognize a problem. Appropriate feedback to personnel on equipment performance, in the form of testing, reports and real time displays, will increase personnel awareness of equipment problems.
- Employee training and awareness of how their actions and the equipment under their control affect heat rate is essential to managing and improving unit performance. Improvement results from knowledge. Unit heat rate will tend to become optimized as plant personnel increase their knowledge of equipment performance and testing.

Heat Rate Management and Improvement

1. **In the short term** (daily – weekly – monthly), continuous improvement is achieved by:

    - Operating the units with controllable parameters as close to target values as possible. Includes review of daily controllable losses report.
    - Maintaining calibrated instrumentation and monitoring systems that provide feedback to plant personnel.
    - Repairing equipment that impact unit heat rate taking into consideration heat rate and market economics.
    - Monitoring equipment performance and conducting equipment performance tests when necessary.
    - Preparing periodic reports and ensuring that plant personnel are informed about the current condition of generating units and equipment. This includes regular (monthly) review of equipment performance trends and heat rate related parameters by plant staff.

2. **In the long term** (annually), continuous improvement is achieved by:

    - Periodically analyzing the deviation between actual and target heat rate and initiating corrective action where possible. This includes evaluating the impact of the maintenance cycle on unit heat rate and evaluating the potential for changes in plant design that will improve unit heat rate. Appropriate maintenance work is planned for overhauls. Equipment improvements are budgeted and implemented.
    - Annually updating the ten year forecast of unit heat rates as part of the plant budgeting process.
    - Having readily available performance information for management decision making.
    - Ensuring that all levels in the plant organization have the appropriate heat rate related training.

Plant Level Roles and Responsibilities

Continuous improvement and management of unit heat rates is the responsibility of all plant personnel.

1. **Management -** Good management of heat rate requires that plant management make optimizing heat rate a priority each day.

2. **Operations** - Operations personnel monitor controllable parameters continuously with EtaPRO software and maintain parameters as close to target values as practicable. Benchmark performance is established by conducting periodic VWO tests with no sootblowers and blowdown closed. Operations personnel conduct cycle isolation checks periodically and after every start-up to ensure that all drains and vents are in their correct position. Heat rate related work orders are appropriately prioritized on the forced outage list so that repairs are completed as soon as practicable. Unit performance and equipment performance combined with other predictive maintenance measures are used to determine if equipment should be overhauled during planned maintenance shut downs.

3. **Maintenance** - Maintenance personnel periodically calibrate key instrumentation required for heat rate and equipment performance monitoring. Equipment deficiencies that impact unit heat rate are corrected taking into consideration heat rate and market economics. High priority work orders directly impacting heat rate are completed on forced outages (as determined by economics). Equipment maintenance during planned overhauls takes into consideration equipment performance.

4. **Plant Performance Engineer:**
    - Monitors unit performance on a daily basis and works with operations personnel to ensure unit is controlled at the best heat rate when not at full load.
    - Works with operations personnel to ensure that unit achieves maximum output when market conditions require full load from each generating unit.
    - Periodically compares unit actual performance to target performance and reports to plant management the causes for the difference.
    - Continuously monitors equipment performance with performance software or conducts periodic tests to assess equipment condition.
    - Works with the plant team to ensure appropriate O&M and Capital monies are budgeted to maintain equipment performance.
    - Works with the plant team to justify and implement equipment upgrades that improve unit performance.
    - Conducts periodic full load capacity tests to validate unit rating.

Corporate Level Roles and Responsibilities

Heat rate related work at the corporate level can be divided into two general functions: 1) Provide technical support to plant personnel for day to day management of heat rate, and 2) Ensure consistent, accurate heat rate information for rate cases and regulatory reporting.

1. **Performance Engineer** - Thermal generation performance technical support is provided by a performance engineer in the Generation Engineering technical support group. The performance engineer:
    - Provides technical support to plant performance engineers for day to day management of heat rate.
    - Conducts and prepares studies requested by corporate management.
    - Provides performance related technical support to the project engineering group, regulation department, environmental department, and other corporate groups as requested.

- Coordinates performance work group meetings and heat rate related training classes for performance engineers.
- Works with plant performance engineers to standardize and maintain “tools” for managing heat rate. This would include PI data historian, performance software EtaPRO/Virtual Plant, and Emerson Enterprise Data Server (EDS).

2. **Combustion Engineer** – Support for coal combustion and related boiler operations is provided by a combustion engineer in the Generation Engineering technical support group. The combustion engineer:
   - Provides technical support to plant performance engineers for day to day management of boiler combustion related issues.
   - Coordinates performance work group meetings and coal combustion related training classes for performance engineers.
   - Establish best practices for combustion improvement and optimization that improve heat rate and reduce derates.
   - Support plant personnel with equipment inspections during scheduled and forced outages.

3. **Heat Rate Process Engineer -** Corporate heat rate related reporting is managed by an individual in the Generation Engineering technical support group. Heat rate data and reports are used for calculating net power costs for rate cases, preparing corporate budgets, financial reports, and for meeting the Company’s reporting obligations for the Energy Policy Act of 2005. Managing these reporting requirements at the corporate level ensures consistency and accurate reporting, and provides a single point of contact for all thermal generation performance related data used by other corporate entities. The corporate heat rate related reporting includes:
   - Preparing and updating historical 4-year average input-output curves for each thermal unit every six months.
   - Preparing a monthly corporate level heat rate report.
   - Preparing an annual heat rate improvement plan report for the Utah Public Utilities Commission (Energy Policy Act of 2005)
   - Provides heat rate related data for outside data requests.

4. **System Analyst -** Administration of performance related software and hardware is performed by individuals in the Generation Engineering technical support group. Central administration of the performance software ensures consistency in the application of the software and seamless operation of the software across the corporate platform. The administrator is responsible for hardware and software related to the plant data historians (OSI PI) and plant performance software (EtaPRO/Virtual Plant). The administrator:
   - Ensures servers at each plant are maintained and backed up.
   - Works with corporate IT to ensure the software and hardware is integrated with corporate system and meets NERC/CIPS requirements.
   - Ensures these tools are available to plant personnel on a 24-7 basis.
   - Supports the Ovation Enterprise Data Server (EDS) tool.

5. **Database Management - AIS, EAS, FMS** - Three other key functions related to heat rate are also managed at the corporate level.
    - Unit availability data is recorded in the Availability Information System (AIS) system:
        - Provides technical support to plant personnel who enter data into the system.
        - Provides quality control of the data.
        - Provides PacifiCorp data to the NERC/GADS system.
        - Provides availability data for rate case calculations and regulatory reporting.
        - Provides availability data for outside data requests.
    - Generation data is recorded in the Energy Accounting System (EAS) and is managed by the Energy Operations Back Office. The EAS is the official record of generation from each of the thermal units. This generation is used to calculate monthly and annual heat rate reports.
    - Fuel consumed quantities and quality are recorded in the Fuel Management System (FMS) and managed by the Fuels Group. Fuel quantities and quality recorded in this data base are used to calculate monthly and annual heat reports.

Equipment – Maintenance Overhaul and Design Upgrades

Maintenance Overhaul

The efficiency of generating units, primarily measured by the heat rate (the ratio of heat input to energy output) degrades gradually as components wear over time. During operation, controllable process parameters are adjusted to optimize the unit's power output compared to its heat input. Typical overhaul work that contributes to improved efficiency and increased availability includes:

Turbine Improvements

- Steam path audit identifying key areas for blade and seal repairs or upgrades.
- Cycle isolation valves and controls
- Removal of turbine blade deposits

Boiler Improvements

- Heat Transfer surface cleaning and repair
- Fuel burner system inspection and repair
- Intelligent Sootblowers used to maintain clean heat transfer surfaces
- Repair and replacement of Airheater seals and baskets
- Repair of air and flue gas ductwork (air-in leakage)

Balance of Plant Improvements

- Boiler Water Chemical Treatment
- Condenser monitoring & cleaning (air-in leakage)
- Cooling Water Treatment
- Feedwater Heaters (maintenance and material upgrades)
- Critical instrumentation
- Pollution control equipment to improve auxiliary power use
- VFD's for large motors to improve auxiliary power use
- Plant lighting to improve auxiliary power use

Operations (Post Outage)

- Combustion control tuning to optimize NOx and CO emissions
- Plant DCS tuning to optimize unit ramp rates and steady state operation

Design Upgrades

When economically justified, efficiency improvements are obtained through major component upgrades of the electricity generating equipment. The most notable examples of upgrades resulting in improved heat rate are steam turbine upgrades and generator upgrades. Turbine upgrades consist of adding additional rows of blades to the rearward section of the turbine shaft (generically known as a "dense pack" configuration), but can also include replacing existing blades, replacing end seals and enhancing seal packing media. Generator upgrades consist of cleaning and rewinding the coils in the stator, and servicing the electromagnetic core. Such upgrade opportunities are analyzed on a case-by-case basis, and are tied to a unit's major overhaul cycle, and, because they are often capital intensive, are only implemented if economically justified.

Dispatch Philosophy

Incremental Generating Cost and Incremental Heat Rate

The dispatch order of generating units is a function of incremental generating costs, transmission line constraints, spinning reserve requirements, and other transmission constraints. The incremental generating costs are calculated from incremental Operations and Maintenance (O&M) costs, incremental fuel costs, and incremental heat rate.

<u>Incremental fuel costs:</u> Some fuel contracts specify a fixed cost per BTU of fuel supplied. In these cases, the incremental cost of fuel is a constant $/mmBTU. Some contracts decrease the price of fuel as the quantity of fuel purchased increases. The incremental cost of fuel in these contracts decreases as the quantity of fuel purchased increases.

<u>Incremental O&M costs:</u> Some plant O&M costs are constant regardless of plant capacity factor. Regular labor, rents, leases, and many maintenance costs are typically "fixed" and independent of plant capacity factor. Other costs are directly proportional to plant capacity factor. Reagent for scrubbers, water treatment chemicals, and ash hauling contract costs are typically "variable" costs that change in direct proportion to net unit output. These variable costs make up the plant incremental O&M costs.

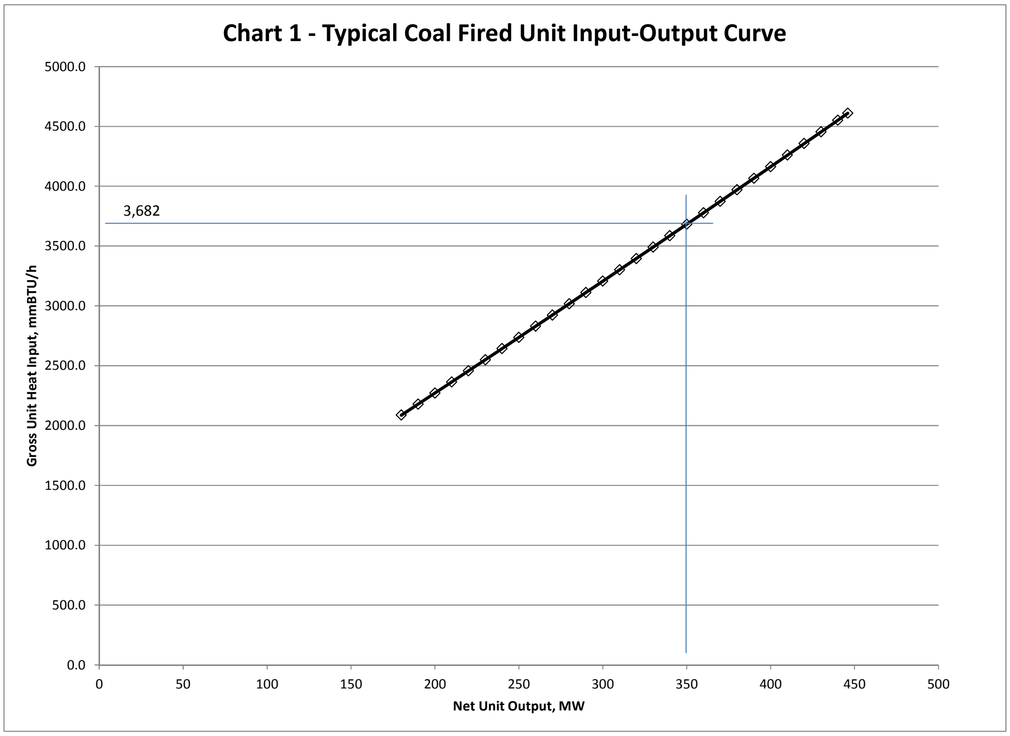
<u>Incremental Heat Rate:</u> Generating unit efficiency varies from minimum load to maximum load. Three curves are used to describe thermal generating unit performance from minimum load to maximum load. The fundamental curve is the "Input-Output" curve that shows the relationship between heat input to the unit and net electrical output out. Chart 1 represents a typical input-output curve for a coal fired unit.

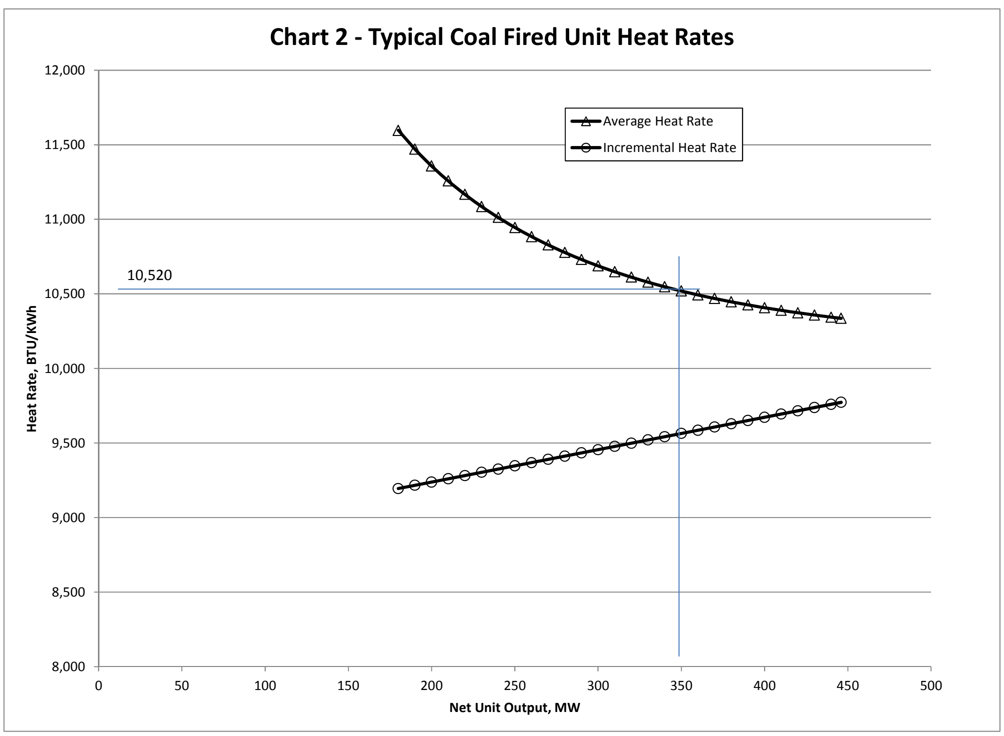
The second curve is the "Heat Rate" curve or more specifically the average heat rate curve. The "average" heat rate is the total BTU heat input at any given output divided by the net unit output. This value is commonly referred to as the unit "heat rate" and is the efficiency of the unit for a net unit output. The average heat rate curve is derived from the Input-Output curve. For example on Chart 1, a load of 350 MW requires a heat input of 3682 mmBTU. The average heat rate is:

$$Average\ Heat\ Rate = \frac{\left(\frac{3{,}682\ mmBTU}{h} * \frac{1{,}000{,}000\ BTU}{mmBTU}\right)}{\left(350\ MWh * \frac{1{,}000\ KWh}{1\ MWh}\right)} = 10{,}520\ \frac{BTU}{KWh}$$

Chart 2 shows that the average heat rate for 350 MW is 10,520 BTU/KWh. The average heat rate of a unit improves (decreases) as the net unit output is increased.

The third curve is the "Incremental Heat Rate" curve or "Incremental" curve. The incremental heat rate is the number of BTUs required to increase the net unit output one more KW. The incremental curve is obtained by taking the derivative of the Input-Output curve or plotting the slope of the Input-Output curve at different outputs. Chart 2 shows the incremental heat rate curve for a typical coal fired unit. The incremental heat rate increases with net unit output.





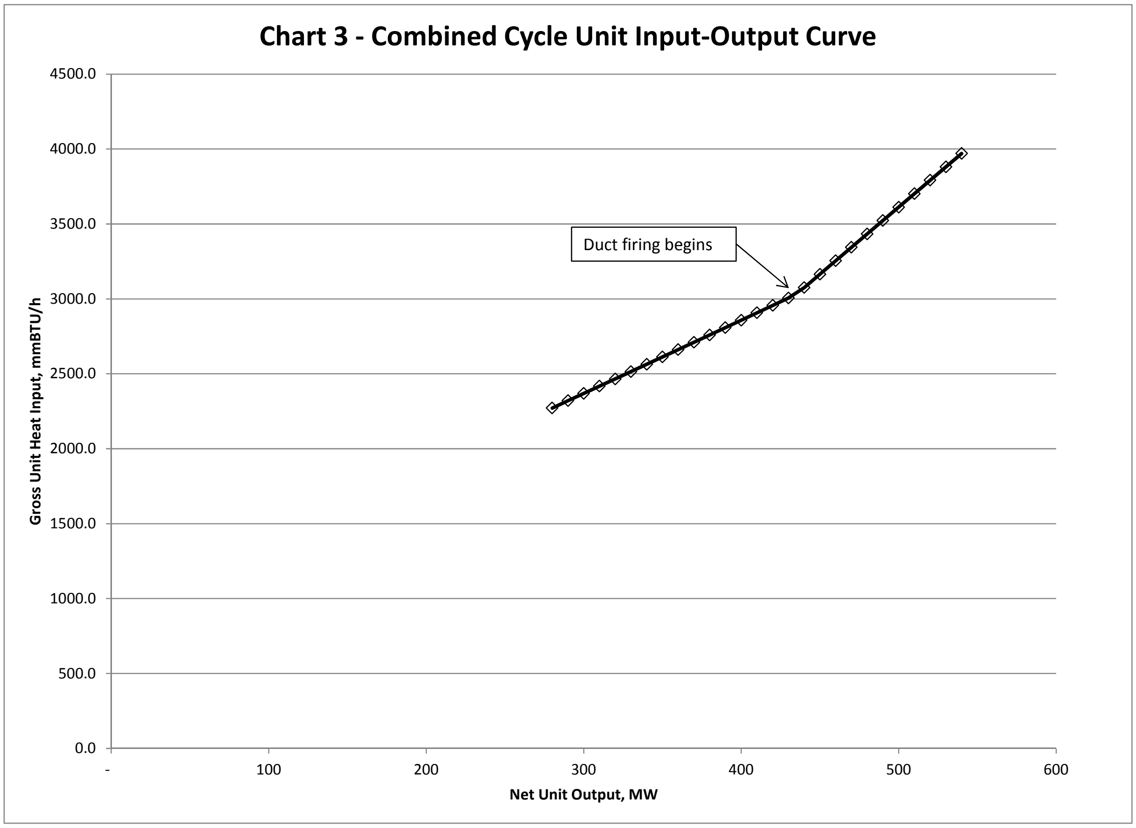


Chart 3 - Combined Cycle Unit Input-Output Curve
Gross Unit Heat Input, mmBTU/h
4500.0
4000.0
3500.0
3000.0
2500.0
2000.0
1500.0
1000.0
500.0
0.0
Duct firing begins
-
100
200
300
400
500
600
Net Unit Output, MW

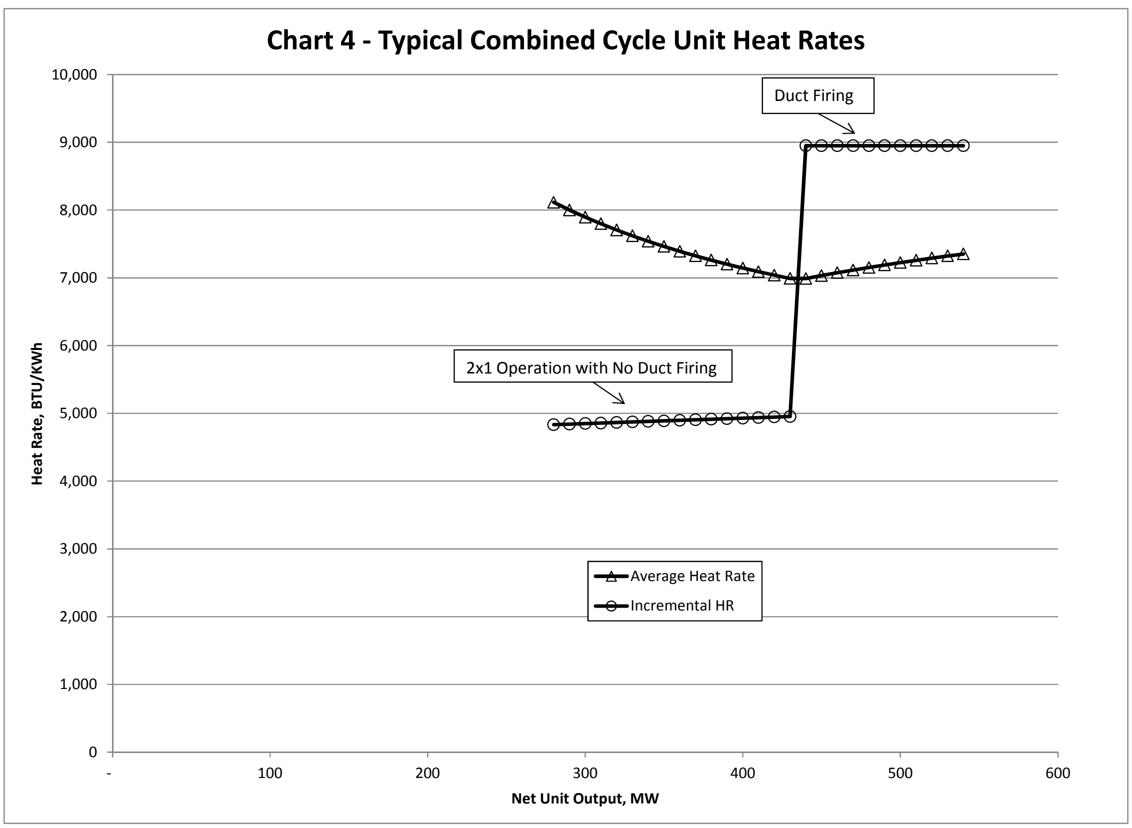


Chart 4 - Typical Combined Cycle Unit Heat Rates
Heat Rate, BTU/KWh
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Duct Firing
2x1 Operation with No Duct Firing
Average Heat Rate
Incremental HR
-
100
200
300
400
500
600
Net Unit Output, MW

Chart 3 and Chart 4 illustrate the curves for a combined cycle unit. Combined cycle units are more efficient than coal fired units. The average heat rates on Chart 4 are lower than the average heat rates on Chart 2. Many combined cycle units are equipped with duct firing to provide additional capacity. Producing MW with duct firing is not as efficient as combined cycle with no duct firing. Chart 3 and Chart 4 illustrate that the heat input for each KW increases when duct firing. Chart 4 shows that the average heat rate improves (becomes less) as unit output increases up to the point of duct firing. After duct firing begins, the heat rate becomes poorer as load increases.

Incremental Generating Costs

Incremental Generating Costs are calculated in the following manner:

$$Incremental\ Generating\ Costs, \$/KWh = IOM + IFC * IHR$$

IOM = Incremental O&M Costs, $/KWh
IFC = Incremental Fuel Costs, $/mmBTU
IHR = Incremental Heat Rate, BTU/KWh

At PacifiCorp, the sale, production, transmission, distribution, and delivery of the electrical product all occur at the same instant of time. The dispatch of the generating units is handled by a dispatch group. This group, in real time, determines which unit will generate the next unit of electrical power. This is always the least cost MW determined by not only the least cost of generation at the plant, but considering the loss due to transmission, and many other factors. The dispatch group always has the most up-to-date values of unit heat rate, and all costs associated with each generating unit and source. This ensures that at any given instant of time that the next MW sold is the one that costs PacifiCorp, and therefore our customers, the least amount of money.

The following Charts 5 and 6 illustrate the differences between incremental generating cost and incremental heat rate. These are only examples and are based on data collected during 2015. It should be noted that units that have the best incremental heat rates do not always have the lowest incremental cost.

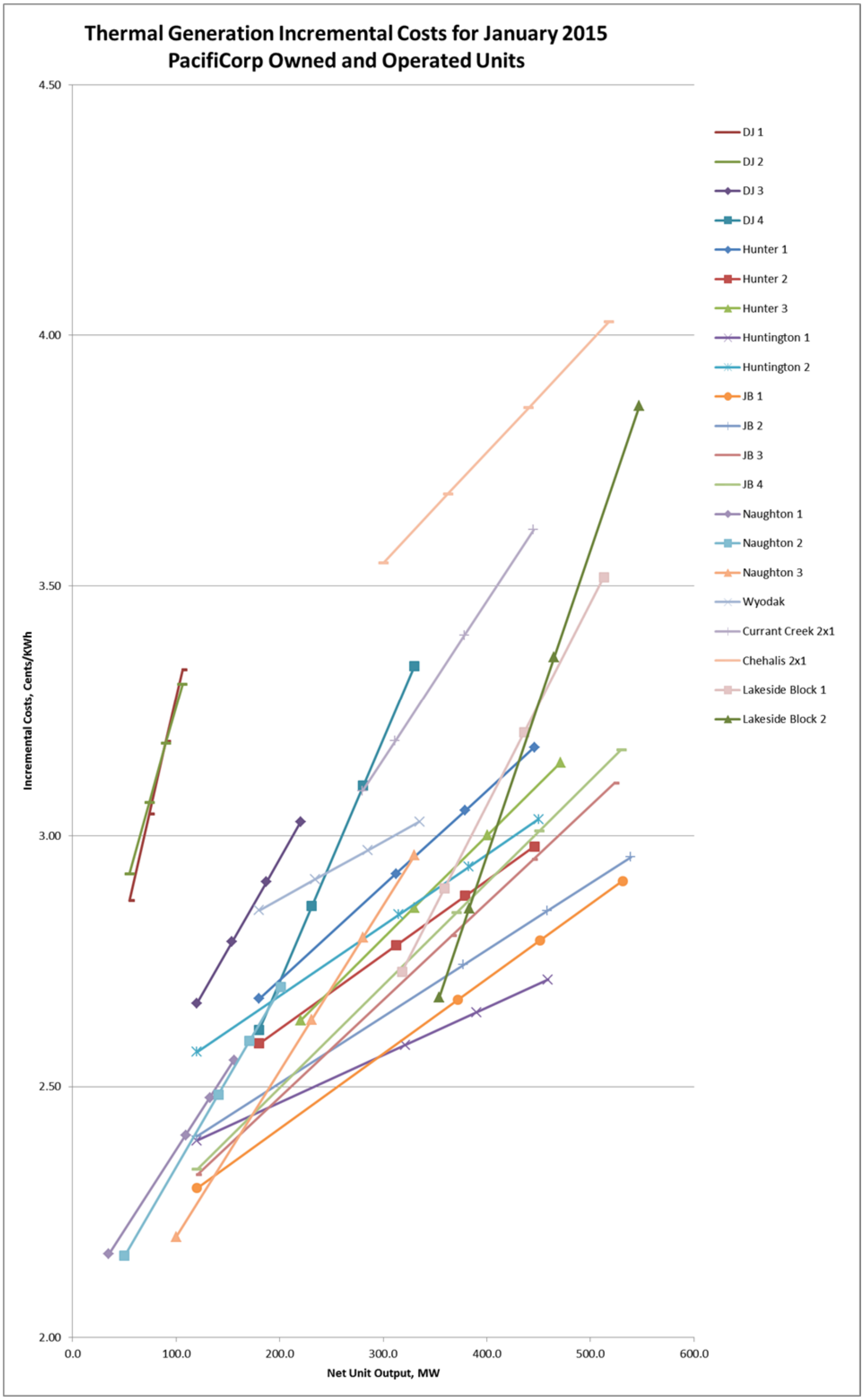


Chart #5 - Incremental Generating Cost Curves

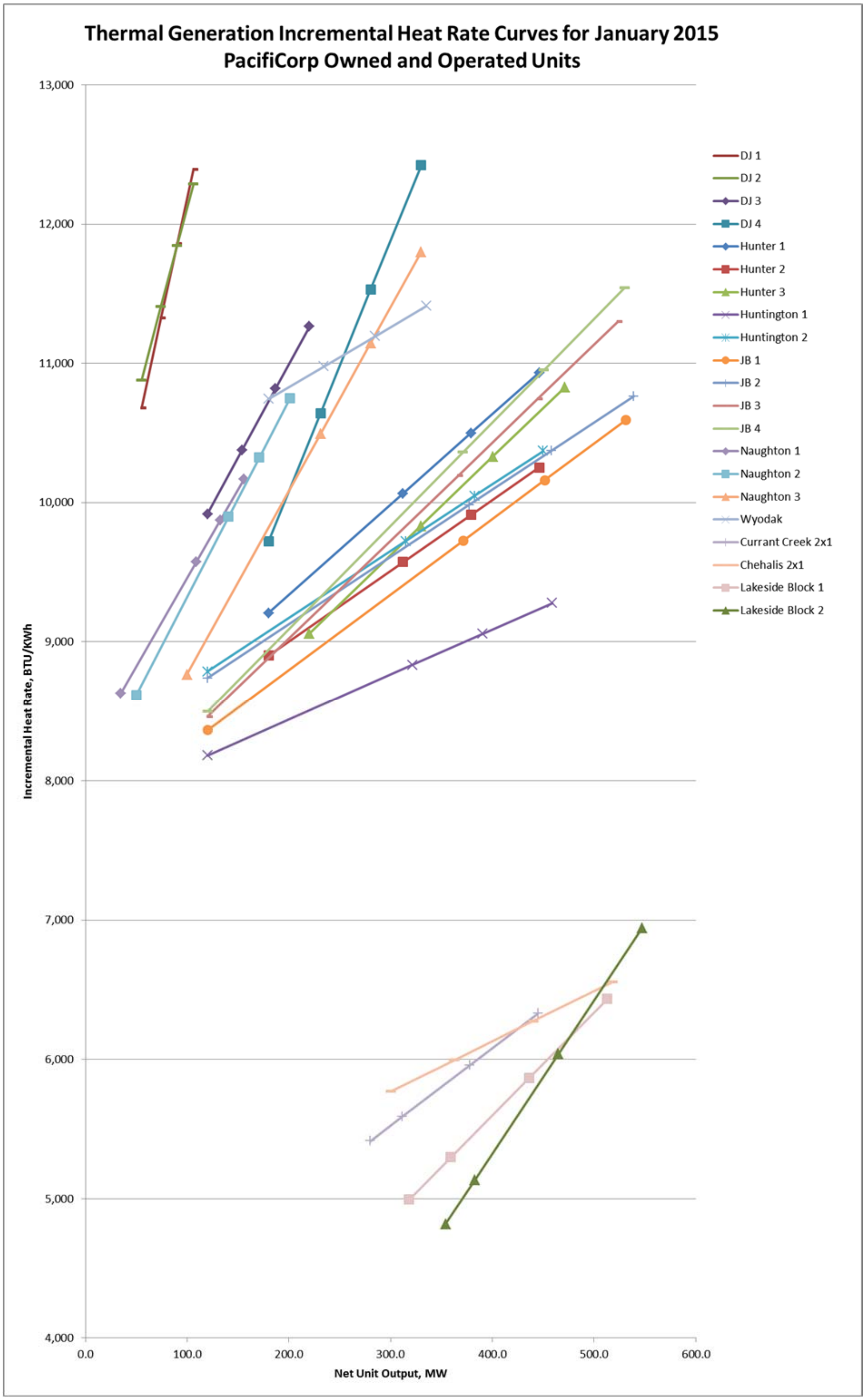


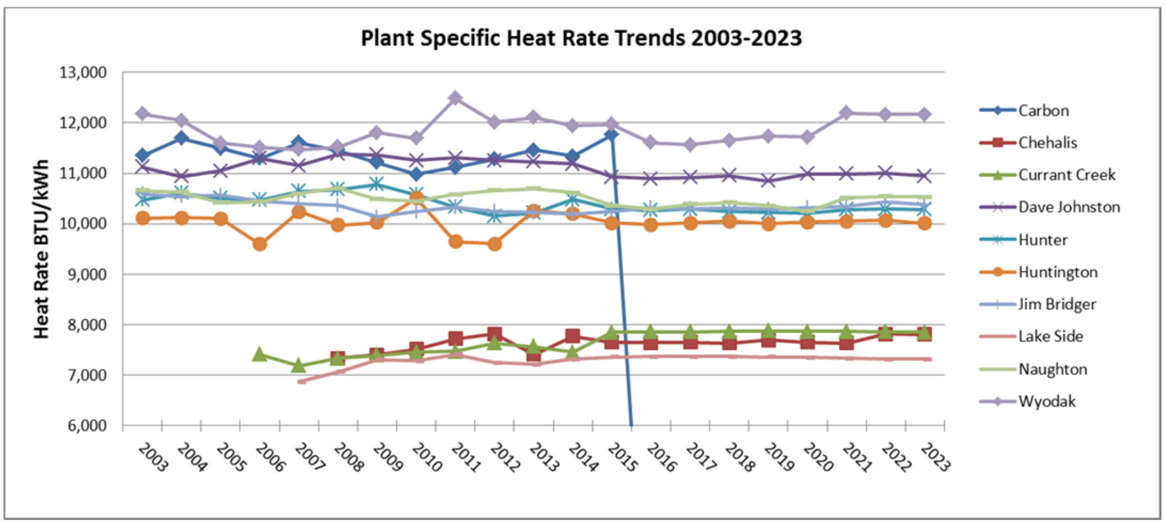
Chart #6 - Incremental Heat Rate Curves

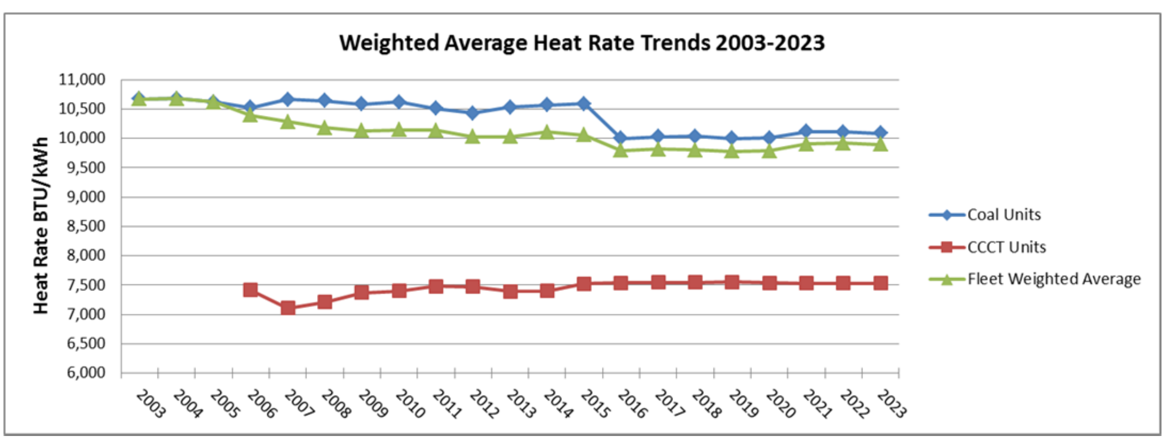
Fleet Heat Rate Trends

10 Year Historical and 10 Year Forecast

The table and two charts below represent both historical and forecast heat rates for each of the PacifiCorp owned and operated plants. The historical data is based on FERC form 1 reports and the forecast data is based on PacifiCorp's 10 year budget forecast. This data shows there is an on-going improvement with the fleet weighted average heat rate.

Plant/Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Carbon	11,346	11,694	11,498	11,295	11,603	11,454	11,209	10,978	11,115	11,279	11,459	11,340	11,767	0	0	0	0	0	0	0	0
Chehalis						7,331	7,401	7,511	7,720	7,817	7,414	7,770	7,648	7,644	7,650	7,632	7,696	7,648	7,631	7,813	7,810
Currant Creek				7,409	7,192	7,331	7,391	7,452	7,468	7,632	7,564	7,450	7,850	7,858	7,862	7,865	7,873	7,866	7,863	7,860	7,852
Dave Johnston	11,122	10,937	11,047	11,300	11,151	11,388	11,365	11,256	11,305	11,259	11,232	11,183	10,932	10,896	10,919	10,953	10,847	10,989	10,989	11,006	10,947
Hunter	10,471	10,613	10,509	10,474	10,642	10,678	10,779	10,572	10,336	10,155	10,217	10,485	10,295	10,266	10,293	10,243	10,222	10,209	10,281	10,289	10,285
Huntington	10,112	10,124	10,099	9,595	10,240	9,972	10,023	10,504	9,644	9,601	10,260	10,195	10,014	9,986	10,021	10,048	9,996	10,030	10,048	10,071	10,004
Jim Bridger	10,591	10,538	10,569	10,453	10,392	10,363	10,138	10,240	10,328	10,251	10,223	10,194	10,250	10,319	10,301	10,313	10,289	10,320	10,345	10,430	10,379
Lake Side					6,872	7,071	7,305	7,280	7,413	7,251	7,213	7,314	7,363	7,365	7,371	7,369	7,364	7,348	7,335	7,318	7,313
Naughton	10,663	10,629	10,425	10,442	10,603	10,704	10,490	10,451	10,585	10,664	10,693	10,620	10,357	10,294	10,388	10,424	10,357	10,252	10,513	10,541	10,536
Wyodak	12,172	12,050	11,597	11,514	11,469	11,520	11,808	11,695	12,482	12,009	12,105	11,939	11,968	11,605	11,562	11,652	11,736	11,723	12,189	12,164	12,163
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Coal Units	10,673	10,676	10,618	10,527	10,662	10,645	10,584	10,619	10,510	10,434	10,534	10,567	10,589	10,001	10,027	10,033	9,997	10,006	10,118	10,108	10,085
CCCT Units				7,416	7,104	7,211	7,371	7,397	7,480	7,474	7,395	7,399	7,522	7,538	7,548	7,546	7,551	7,535	7,532	7,529	7,528
Fleet Weighted Average	10,673	10,676	10,618	10,391	10,284	10,183	10,129	10,145	10,140	10,027	10,031	10,110	10,060	9,795	9,816	9,800	9,783	9,787	9,902	9,919	9,898





10 Year Capital Project List Effecting Heat Rate

The following capital projects have been identified that reduce the thermal units' performance, including:

Plant	Unit	Project Description	Year	Unit HR Effect Btu/KWh	Measure	Project Number	Estimated Cost
Dave Johnston	1	Mercury Capture	2015	2	HR Increase	10002178	$2,035,000
Dave Johnston	2	Mercury Capture	2015	2	HR Increase	10002179	$2,035,000
Dave Johnston	3	Mercury Capture	2015	2	HR Increase	10002180	$2,961,094
Dave Johnston	4	Mercury Capture	2015	2	HR Increase	10002181	$2,961,094
Hunter	1	SCR Addition	2024	36	HR Increase	10009397	$128,352,593
Hunter	3	SCR Addition	2022	36	HR Increase	10002885	$178,558,558
Jim Bridger	1	Mercury Capture	2015	2	HR Increase	10003392	$1,164,545
Jim Bridger	2	Mercury Capture	2015	2	HR Increase	10003393	$1,164,545
Jim Bridger	3	Mercury Capture	2015	2	HR Increase	10003394	$1,164,545
Jim Bridger	4	Mercury Capture	2015	2	HR Increase	10003395	$1,164,545
Jim Bridger	1	SCR Addition	2022	57	HR Increase	1003391	$117,521,380
Jim Bridger	2	SCR Addition	2021	57	HR Increase	1003395	$115,262,310
Jim Bridger	3	SCR Addition	2015	57	HR Increase	10003396	$157,660,078
Jim Bridger	4	SCR Addition	2016	57	HR Increase	1009398	$193,399,446
Naughton	1	Mercury Capture	2015	2	HR Increase	10003749	$1,187,500
Naughton	2	Mercury Capture	2015	2	HR Increase	10003750	$1,187,500
Wyodak	1	Mercury Capture	2015	2	HR Increase	10004048	$2,961,094
Total				322	HR Increase		$910,740,827

Each of these projects increases the thermal units' auxiliary power consumption of electric power, thereby reducing our efficiency and increasing our unit heat rate.

Appendix A: IRP Preferred Portfolio 2015-2034:

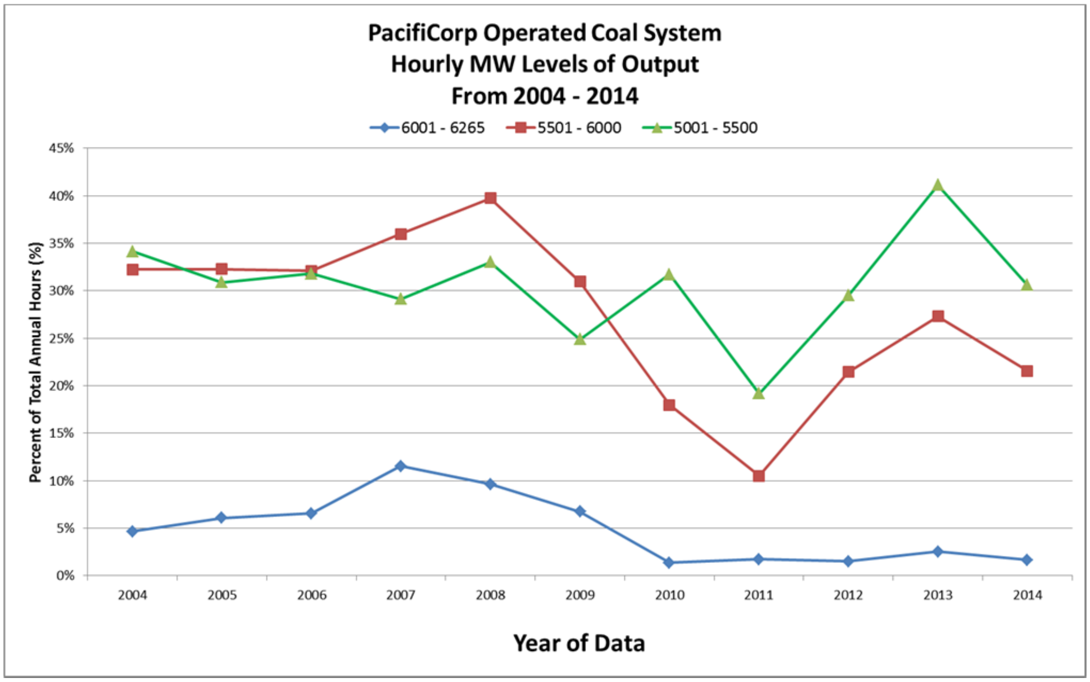
This table is from PacifiCorp's 2015 Integrated Resource Plan (IRP), Chapter 8. It describes new resources that would become available and old resources and the anticipated retirement years.

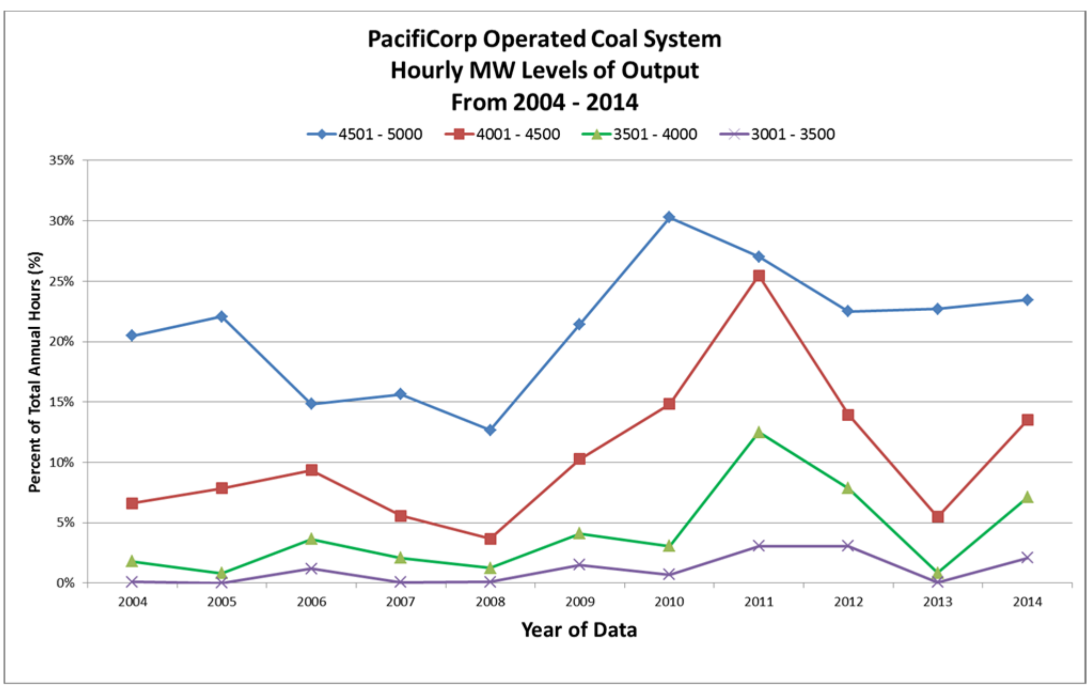
	Preferred Portfolio (Case C05a-3Q)	Nameplate Capacity (MW)																				Resource Totals 1/	
		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	10-year	20-year
East	**Existing Plant Retirements/Conversions**																						
	Hayden 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(45)	-	-	-	-	(45)
	Hayden 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(33)	-	-	-	-	(33)
	Hunter 2 (Coal Early Retirement/Conversions)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(269)	-	-	(269)
	Huntington 2 (Coal Early Retirement/Conversions)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(450)	-	-	-	-	-	(450)
	Carbon 1 (Coal Early Retirement/Conversions)	(67)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(67)	(67)
	Carbon 2 (Coal Early Retirement/Conversions)	(105)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(105)	(105)
	Cholla 4 (Coal Early Retirement/Conversions)	-	-	-	-	-	-	-	-	-	-	(387)	-	-	-	-	-	-	-	-	-	-	(387)
	DaveJohnston 1	-	-	-	-	-	-	-	-	-	-	-	-	-	(106)	-	-	-	-	-	-	-	(106)
	DaveJohnston 2	-	-	-	-	-	-	-	-	-	-	-	-	-	(106)	-	-	-	-	-	-	-	(106)
	DaveJohnston 3	-	-	-	-	-	-	-	-	-	-	-	-	-	(220)	-	-	-	-	-	-	-	(220)
	DaveJohnston 4	-	-	-	-	-	-	-	-	-	-	-	-	-	(330)	-	-	-	-	-	-	-	(330)
	Naughton 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(156)	-	-	-	-	-	(156)
	Naughton 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(201)	-	-	-	-	-	(201)
	Naughton 3 (Coal Early Retirement/Conversions)	(50)	-	-	(280)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(330)	(330)
	Gadsby 1-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	(358)	-	-	(358)
	Coal Rat_AZ - Gas RePower	-	-	-	-	-	-	-	-	-	-	387	-	-	-	-	-	-	-	-	-	-	387
	Coal Rat_WY - Gas RePower	-	-	-	337	-	-	-	-	-	-	-	-	-	-	-	(337)	-	-	-	-	337	-
	Expansion Resources																						
	CCCT - DJohns - F 1x1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	313	-	-	-	-	-	313
	CCCT - DJohns - J 1x1	-	-	-	-	-	-	-	-	-	-	-	-	-	423	-	-	-	-	-	-	-	423
	CCCT - Utah-N - F 2x1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	635	635	-	1,270
	CCCT - Utah-S - J 1x1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	846	-	-	-	-	-	846
	Total CCCT	-	-	-	-	-	-	-	-	-	-	-	-	-	423	-	1,159	-	-	635	635	-	2,852
	DSM, Class 1, UT-DLC-RES	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9	-	-	4.9
	DSM, Class 1 Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9	-	-	4.9
	DSM, Class 2, ID	4	4	5	5	5	4	4	4	5	5	5	5	5	5	5	4	4	4	5	4	45	90
	DSM, Class 2, UT	69	78	84	86	92	81	84	90	91	93	75	76	80	80	77	75	72	72	73	70	847	1,596
	DSM, Class 2, WY	6	8	10	12	14	12	13	14	15	16	13	13	14	15	15	15	16	16	17	17	121	271
	DSM, Class 2 Total	79	90	99	102	111	97	101	108	110	114	92	94	99	99	97	94	93	92	94	92	1,012	1,958
	FOT Mona Q3	-	-	-	-	-	-	-	-	-	-	-	-	-	161	44	110	104	268	300	74	-	53
West	**Expansion Resources**																						
	Oregon Solar Capacity Standard	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	7
	DSM, Class 1, OR-Curtail	-	-	-	-	-	-	-	-	10.6	-	-	10.6	-	-	10.6	-	-	-	-	-	10.6	31.8
	DSM, Class 1, OR-Irrigate	-	-	-	-	-	-	-	5.0	-	-	-	-	-	-	-	-	-	-	-	-	5.0	5.0
	DSM, Class 1 Total	-	-	-	-	-	-	-	5.0	10.6	-	-	10.6	-	-	10.6	-	-	-	-	-	15.6	36.8
	DSM, Class 2, CA	1	2	2	2	2	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1	16	29
	DSM, Class 2, OR	44	39	36	33	29	27	25	25	23	23	21	22	22	22	21	21	20	21	20	20	303	511
	DSM, Class 2, WA	8	9	10	10	11	9	10	10	11	11	9	9	9	9	9	8	8	8	8	7	98	181
	DSM, Class 2 Total	54	49	47	44	42	38	36	36	36	35	31	32	32	32	31	30	29	30	28	28	417	721
	FOT COB Q3	-	62	29	-	60	104	-	-	-	-	-	-	-	268	248	268	268	268	185	138	26	95
	FOT MidColumbia Q3	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
	FOT MidColumbia Q3 - 2	227	375	375	370	375	375	269	291	261	254	271	292	335	375	375	375	375	375	375	375	317	335
	FOT NOB Q3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
	Existing Plant Retirements/Conversions	(222)	-	-	57	-	-	-	-	-	-	-	-	-	(762)	-	(1,144)	(77)	-	(627)	-		
	Annual Additions, Long Term Resources	133	146	146	146	153	135	137	149	157	149	123	137	130	555	139	1,284	122	122	762	755		
	Annual Additions, Short Term Resources	727	937	904	870	935	979	769	791	761	754	771	792	835	1,304	1,167	1,253	1,247	1,411	1,360	1,087		
	Total Annual Additions	860	1,084	1,050	1,016	1,088	1,113	906	941	917	903	893	928	965	1,859	1,305	2,537	1,369	1,533	2,123	1,841		

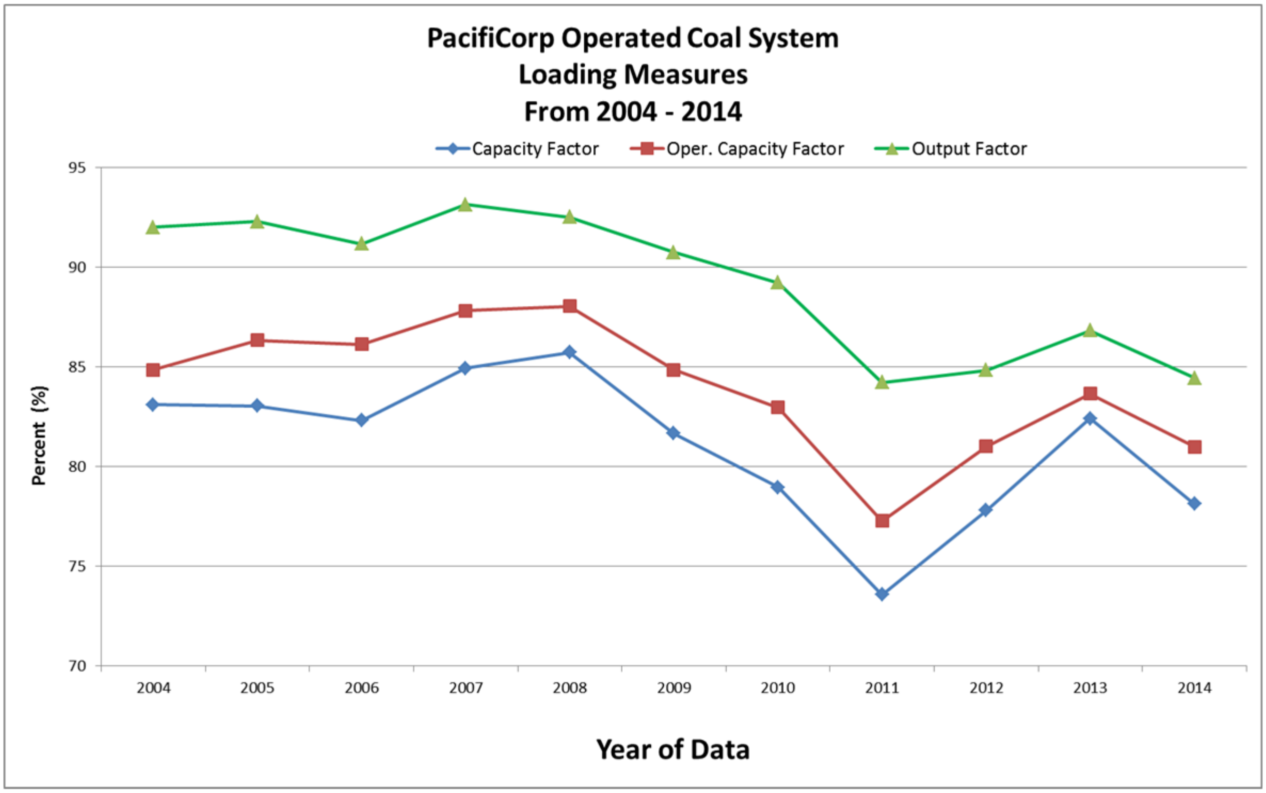
1/ Front office transaction amounts reflect one-year transaction periods, are not additive, and are reported as a 10/20-year annual average.

Appendix B: PacifiCorp Owned and Operated Coal Fleet MW Output Levels

Per request of the commission, the following charts are provided to illustrate the capacities and output of the coal fleet. Each line on the first two charts represents a MW output range and the percent total annual hours at that range. The third chart represents the capacity factor, operating capacity factor and the output factor of the coal fleet. In general, these charts indicate that the coal fleet has been operating at reduced capacity through to 2011. From 2011 to 2013 there has been an increase and then there has been a decrease in 2014.






PacifiCorp Operated Coal System
Loading Measures
From 2004 - 2014
Capacity Factor
Oper. Capacity Factor
Output Factor
Percent (%)
95
90
85
80
75
70
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
Year of Data

Signature Page

Corporate Heat Rate Engineer		Brandon Humble	
Signature:		Date:	28 April 2015

Manager Engineering/Environmental		Greg Hunter	
Signature:		Date:	28 April 2015

Managing Director, Generation Support		Rod Roberts	
Signature:	Rod Roberts	Date:	28 April 2015