June 18, 2015

MEMORANDUM

TO: John Conti
Assistant Administrator for Energy Analysis

Jim Diefenderfer
Director, Office of Electricity, Coal, Nuclear, and Renewables Analysis

FROM: Coal and Uranium Analysis Team

SUBJECT: Notes from the **Future Operating and Maintenance Considerations for the Existing Fleet of Coal-fired Power Plants** workshop held on June 16, 2015

Attendees (43)

Name	Affiliation
Adams, Greg	US DOE: EIA
Broedin, Joerg	Alstom
Sutton, Jim	Alstom
Usher, Matt	American Electric Power
Staudt, James	Andover Technology Partners
Goffard, Scott	Babcock & Wilcox
Angielski, Shannon	Coal Utilization Research Council (CURC)
Fisher, Emily	Edison Electric Institute (EEI)
James, Revis	Electric Power Research Institute (EPRI)
White, Larry	Mitsubishi Hitachi Power Systems America
Williams, Jacob	Peabody Energy
Grol, Eric	US DOE: FE/NETL
Kern, Kenneth	US DOE: FE/NETL
O'Donnell, Mike	Babcock & Wilcox
Henderson, Mark	Coal Utilization Research Council (CURC)
Yamagata, Ben	Coal Utilization Research Council (CURC)
Pullen, George	Commodities Futures Trading Commission
Obenshain, Karen	Edison Electric Institute (EEI)
Petersen, Eric	Rolls Royce
Bailie, Alison	Union of Concerned Scientists
Peters, Jamie	Union Pacific Railroad
Schmalzer, David	US DOE: Argonne National Laboratory
Aniti, Lori	US DOE: EIA
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Martin, Laura	US DOE: EIA
Mellish, Michael	US DOE: EIA
Park, Brian	US DOE: EIA
Satsangi, Ann	US DOE: FE/HQ
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Breckel, Alex	US DOE: Office of Energy Policy & Systems Analysis (EPSA)
Dell, Rebecca	US DOE: Office of Energy Policy & Systems Analysis (EPSA)
Kleiner, Elaine	US DOI: Bureau of Safety and Environmental Enforcement (BSEE)
Anderson, Steve	US DOI: USGS
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Moxness, Greg	US DOL: MSHA
Stevens, William	US EPA

Framing the question

Per National Energy Technology Laboratory (NETL) analysis, between 1998 and 2014, 72% of all of the kilowatthours were baseload (where 59% was coal; 33% nuclear; and 8% natural gas), where baseload is defined as capacity that operated at an average annual capacity factor of at least 65%. In looking at age bands over this period of time, NETL found that at the age of 50, there is a sudden drop-off in utilization. Today, the average age of coal plants is 45. In 2020, because of projected retirements in the prior years, the average age is still projected to be about 45. In 2030, the average age will be 55, and in 2040, it will be 65. Weighted on capacity, the average age in 2040 will be about 62. In 2040, 88% or 224 GW of coal-fired generating capacity will be greater than 50 years old. By 2030, two-thirds of the capacity will be greater than 50 years of age. The NETL analysis shows no obvious difference in performance – in terms of capacity factors -- between subcritical and supercritical plants. A declining capacity factor after age 50 in the historical data may partly be attributable to avoiding the triggering of NSR regulations. NETL wonders if it reasonable to expect the aging coal fleet to operate at high capacity utilizations in 2040 and is interested in identifying technical or other limiting factors that should be addressed.

NETL raised the concern that there is a potential for overestimation of kilowatthours from coal generation in EIA's analysis, if capacity factors for the aging coal fleet in the future are presumed to reflect the historical values. NETL's analysis suggests that this overestimation could be as large as 1000 billion kilowatthours (or an associated capacity of well over 100 GW). NETL stated that, as the fleet deteriorates, new baseload capacity will be needed to maintain this level of generation.

The following items were viewpoints – grouped roughly by subject matter --that were offered during the discussion. Their inclusion below does not necessarily mean that attendees reached consensus on these topics.

Understanding the historical lower utilization of older plants

• Older plants were used less historically. The older plants tended to be smaller subcritical units built in the East. These plants were designed to burn eastern coal which has become increasingly expensive over time –encouraging a lower utilization of those plants. New more efficient coal plants–designed to take other types of lower cost coal -- were also added to the fleet over this period and proved to be comparatively more economic as eastern fuel prices rose. This, combined with the concerns about triggering NSR, contributed to the lower capacity factor of older coal plants relative to younger plants (rather than age).

• In the future, with little additional coal builds, there will not be newer coal capacity to replace older plants in dispatch. The average coal fleet capacity factor will be driven primarily by the total power demand and the outcome of coal-on-natural-gas competition, which have been rigorously modeled in NEMS. Historically, the older plants were simply less cost-competitive.

How are O&M decisions made?

• Little money is spent on plants – on a gradual, anticipatory basis– strictly to enhance longevity.

• Supercritical plants have been designed so that a majority of the components are replaceable.

• The decision to replace components is an economic one. There is not a technically limiting factor.

• NETL indicated that while plant owners are likely to perform major maintenance at a coal-fired generating unit when it reaches about 30 years in age, owners may not want to do that same maintenance when a plant reaches age 60, and may opt for retirement instead.

• One person commented that there is greater spending on supercritical than subcritical plants; another person stated there was no reason to believe that spending would be different for supercritical compared to subcritical plants.

• There is not a single plant component whose replacement would be a show stopper in terms of technical feasibility. For example, there is historical precedence for the replacement of steam drums.

• Major maintenance also may require the plant to shut down for significant time which is another major factor in investment decisions.

• Current owners of coal power plants differ in experience and ability to make large investment decisions.

Retirement decisions

• Future decisions to retire will likely be more difficult to make. There is a need to support renewable generation – perhaps not the biggest factor for most plants. Because of the difficulty in sighting new assets, there may be less willingness to let go of existing assets. In addition, the role that a plant may play for reliability may be difficult to assign an economic value.

• Water issues, i.e. closed loop versus open loop, are not yet impacting retirement decisions.

• Safety can be a real world concern that encourages replacement or shutdown; safety concerns will always trump economics, i.e., if a corrosion issue with a particular boiler becomes too significant of an issue.

• There is uncertainty regarding whether or not fixed O&M costs are all that important for retirement decisions, with market conditions for a plant perhaps being a much more important factor.

• Plants that retired during the past couple of years were older or forced out due to emissions.

• The older plants were over-designed beyond necessary specifications, including safety specifications. Units built 50 years ago were built better than ones built during say the 1980s.

Utilization (capacity factor) volatility, i.e. cycling, and associated wear-and-tear:

• The definition of cycling can vary. Three definitions include: (1)turning the plant off and then on (cold-start), (2) rapid load ramp-up rates, and (3) pushing plants to operate at non-design utilization rates.

• There is a general concern about the wear-and-tear on coal plants due to the operation of the plants at levels below their original design rather than the operation of these plants at higher utilization rates. Higher utilization rates would tend to prolong the life of a coal plant.

• Some potential problems related to lower utilization include temperature control for proper operation of selective catalytic reduction equipment (SCRs) and maintenance and control of proper water chemistry to control corrosion.

• Certain plant components – like the heat exchanger – are more susceptible to damage from repeated starts and stops.

• Units will need a major refurbishment to operate at higher utilization in 2040.

• WorleyParsons conducted a study for NETL including the derivation of a list of components susceptible to replacement if plants are operating with greater frequency of cold starts.

• NETL tried to quantify the impact of a lower utilization on heat rate. For such suboptimal operation, NETL derived an incremental dispatch cost of about $4/mWh which would move plants up the dispatch curve by a meaningful amount. In regions like PJM such an incremental cost could be significant.

• Generators do not really know what the long-term effects and maintenance requirements are due to the cycling of coal plants that are not originally designed to by cycled.

• SCRs require an appropriate inlet temperature. There are ways that operators can circumvent this requirement in a cycling environment, but there is a cost.

• The use of new materials – designed to be more forgiving under stressful conditions like change in temperatures and pressure -- may help to make coal plants more resilient.

• Turbines designed for base or peak loads are less efficient when operated in their non-design mode.

• Supercritical coal plants require tight specifications of water chemistry that impact operation. Certain chemicals may leach out and contribute to increased corrosion. A steady state of operation is important to anticipate water chemistry composition.

• A supercritical plant requires 10 to 12 hours to ramp up from a cold start. A subcritical plant requires less time (approximately 8 hours); minimum required operation level at ~40% of capacity.

• Though the relationship between utilization and heat rate varies by plant, there is about a 5% variability potential.

• Supercritical plants require higher temperatures and pressures than subcritical plants. 71% of the coal fleet is subcritical and 29% will be supercritical. If we presume that the majority of retirements are subcritical, we will be relying on supercritical plants to cycle.

• Operators today are better at identifying and managing deteriorating conditions at plants.

• There are different operating philosophies at different companies. For example, some do not have chemists on-site at plants while others do.

• Incorrect foresight of the duration of a pro-longed layup (e.g. 2 weeks turning into 3 months) can have implications for the resiliency of a plant.

• There are potential issues of cycling with regard to emission rates, as these rates were established for a plant operating at optimal operating conditions. If the permit for a plant ties the plant to a particular emission rate and could result in compliance problems, especially if CO_2 is included in the permit.

• Any crew can be trained to operating in cycling mode.

New Source Review

• If efficiency improves and a plant is more economical to dispatch, it also could have the potential to emit more pollutants (based upon pre-construction permitting analysis). Therefore, a plant could be subject to New Source Review (NSR).

• If a plant has the potential to emit more of one pollutant covered under NSR, all pollutants must be analyzed to determine if Best Available Control Technology (BACT) must be implemented. To complicate matters, certain standards can change over time (e.g. NSPS and NAAQS).

• CO2 is now a NSR pollutant according to a court ruling last year.

• A plant whose capacity factor rises from 50% to 80% could trigger NSR.

• There is a long legal history of the debate over what constitutes a typical O&M cost versus an equipment upgrade.

• The Clean Power Plan (CPP) Block 1 will likely trigger NSR; the 6% efficiency improvement potential assumed by Block 1 is a large number. NERC analysis of the CPP showed average annual capacity factors for coal plants dropping to a range of 11-19%.

• If a plant is assumed to operate at a lower utilization, the investment may not be recouped, but if the efficiency is improved, NSR will likely be triggered.

• Retrofits of activated carbon injection (ACI) or dry sorbent injection (DSI) systems will not likely trigger NSR. A lot of small marginal units have been retired or converted to natural gas. The biggest NSR issue is probably going to be triggered by 111(d).

• There are probably not that many near-term NSR issues, but they could pop up 8 years down the road when New Source Performance Standards (NSPS) are reviewed.

• NSR is part of the larger Prevention of Significant Deterioration (PSD) Program.

• Utilities spend a lot of money on legal issues related to NSR allegations.

• Impact of environmental regulations may tend to favor larger coal units.

• On/off cycling has the most effect on a coal unit, followed by rapid load regulation and cycling.

Modeling issues and advice

• Energy models generally tend to retire few generation assets.

• NEMS assesses the economic viability of existing coal plants using levelized costs. $7/kW-year with $9 adder after 30 years is the aging related cost adder used by EIA and roughly equates to NETL's presumed $512/kW (+/- 60% depending on site, unit design, etc.).

• Economic and financial factors are the main drivers for coal plant future capacity factors. The economic life of old coal plants could be extended, should the plant owners have the financial capability to make the large lump-sum capital investment that is often required for such extension. In reality, not all plant owners have such financial capability.

• The EIA methodology does not capture the financial challenges associated with lump sum capital payments for expensive one-time upgrades. A modeling method to present these costs in a more 'lumpy' fashion and not in a way that anticipates future slow deterioration should be considered. One thought is to somehow consider incorporating costs on a cash flow basis.

• The IPM model used for EPA studies includes gradual age-based increases in fixed O&M costs for coal plants.

• It would be difficult and controversial to model differences in plant ownership as a factor to influence retirement decisions.

• The recommendation was made that EIA should acknowledge uncertainty regarding the U.S. coal fleet's ability to operate at high capacity factors through 2040; EIA might consider capping utilization rates in the later years of the projection.

Miscellaneous

• A question arose as to whether or not the 3% cost of capital adder was still included in the policy runs made for EIA's Clean Power Plan (CPP) analysis. The person felt that it should have been removed for the CPP policy runs, as the CPP removes the uncertainties regarding CO2 emissions. While EIA staff was not able to answer this question at the discussion, they were able to check up on this after returning to the office and determine that the 3% adder was not excluded in the policy runs, although it would only have been applied to capital investments for retrofits of non-CO2-related equipment, as no new builds of coal capacity without CCS were permitted in the CPP policy runs.

• A recommendation was made that EIA should do a run with an advanced coal portfolio standard to see what that does to the projected price of electricity.

• One individual recommended a more diverse representation of coal technologies in the modeling including hybrid systems (e.g. coal plus solar for CO2 capture, sorbent use for CO2 removal, different unit sizes). Another suggested looking into advanced renewables further from a modeling perspective.

• Reliability pricing may be an area of possible future research.

• Lack of diversification in the generation portfolio – i.e. excluding coal – could limit future options and could be investigated further.

• Other options not specific to EIA for further research included more pilot programs for coal technologies, further support for developing ultra-super-critical coal units, technologies to improve flexibility of the fleet.

• Capacity markets do not exist across the country. PJM has one, but most ISO's do not.

• On commenter suggested that EIA be clear about assumptions pertaining to aging and say if a particular issue cannot be modeled to extent possible.

• CURC and EPRI published a joint report in July 2015 entitled *The CURC-EPRI Advanced Coal Technology Roadmap* that defines the research, development and demonstration necessary for coal to be cost competitive with and have similar performance characteristic as other low emitting power platforms and energy conversion technologies.

Agenda

Future Operating and Maintenance Considerations for the Existing Fleet of Coal-fired Power Plants
Renaissance Downtown Hotel in Washington, DC (Meeting Room 5)
June 16, 1:45 to 5:30
Dial In Information
USA Toll-Free: 888-431-3632
Access Code: 6638158

- 1:45 to 1:55 – Opening Remarks – What Questions Does EIA Need to Address? – Greg Adams, EIA
- 1:55 to 2:05 – Introductions
- 2:05 to 2:20 – Defining the Problem – Ken Kern, NETL
- 2:20 to 3:10 – **Panel 1: Power industry** – Objective: To understand the criteria considered by an operator of a coal generating unit in deciding whether the unit needs major maintenance or upgrades and whether the required capital investment can be justified.
    - AEP – Matt Usher
    - EPRI– Revis James
- 3:10 to 3:20 – Break
- 3:20 to 4:25 – **Panel 2: Equipment and service providers** – Objective: To understand the engineering of different classes and ages of boilers and to understand the performance characteristics and ability to operate those systems as non-baseload (cycling) systems.
    - Alstom – Jim Sutton and Joerg Broedin
    - Babcock & Wilcox – Scott Gossard
    - Mitsubishi Power Systems Power Systems America – Larry White
    - NETL – Eric Grol
- 4:25 to 4:30 – Break
- 4:30 to 5:20 – **Panel 3: Government** – Challenges with New Source Review in maintenance and operations of existing fleet, and the 111(d) Implications for Fleet Aging.
    - Independent Consultant – James E. Staudt
    - Edison Electric Institute – Emily Fisher
    - AEP – Matt Usher
- 5:20 to 5:30 – Concluding Remarks

SUPPLEMENTAL MEETING INFORMATION

In order to project the availability of coal-based generators in its AEO projections, the EIA makes assumptions about both the maximum capacity factors at which existing coal plants may operate and the annualized capital costs (in 2012 dollars) required to keep a plant operating over time.

- In the first year of the projections, the maximum capacity factor a coal unit may run at is set to the greater of either the actual, previous 5-year average capacity factor or 50%. If the maximum capacity factor in the first year is less than or equal to 75%, it increases linearly each year towards 75% by 2025, where it remains through 2040. If the actual, previous 5-year average capacity factor is already at or above 75%, the maximum capacity is set to that value and stays there throughout the forecast.
- The average annualized capital additions for existing plants are $17 per kilowatt (kW)-year for coal plants, $8 per for oil and gas steam plants, and $22 for nuclear plants regardless of age. Beyond 30 years of age an additional $7 per kW-year capital charge for fossil plants and $33 for nuclear plants is included in the retirement decision to reflect further investment to address the impacts of aging

NETL has pointed out to EIA that these assumptions should be analyzed further by EIA based on their assessments of the current fleet age, technology composition, and the potential for increased cycling. NETL and EIA met with the Coal Utilization Research Council (CURC) at their meeting in Pittsburgh on March 17th to scope out the issue and identify questions that EIA seeks input to address, including:

- Are there technical or engineering constraints on maintaining capacity factors at aging facilities that cannot be overcome with incremental capital expenditures?
- What is the cost profile for an aging coal plant? How does the cost profile vary by type of plant design?
- What factors (e.g. mechanical, regulatory, electricity demand and/or operating costs) influence life expectancy and costs to operate?
- Which existing, regulatory constraints will have an impact on the life expectancy of the existing fleet through 2050?
- How would increased cycling affect the operation and lifetime of aging coal plants?

The panels would be focused as follows to elicit answers to these questions.

Panel 1: Power industry [50 Minutes] – Objective: To understand the criteria considered by an operator of a coal generating unit in deciding whether the unit needs major maintenance or upgrades and whether the required capital investment can be justified.

a. Can coal units sustain a 75% capacity factors as they age?
b. What is the basis upon which an owner/operator will decide to perform major maintenance or upgrades on an existing unit?
    i. Cost/benefit analysis (components considered in making such a decision: commodity prices, decommissioning cost, etc.)
    ii. Regulatory impediments (uncertainty of future CO2 regulation)
c. Do you project different aging patterns (and maintenance required) for different technologies (subcritical, supercritical, fluidized bed) and how will this affect decisions to make maintenance expenditures?

d. Has any change (increase) in operational limitations or maintenance costs been observed due to aging or increased cycling and load following? (If sufficient experience is not yet available, what are your projections?)
e. Are there any lessons that can be learned from the European experience in regularly cycling coal plants?
f. Are similar operational limitations expected to be observed in the NGCC fleet? If so, is the effect expected to occur over an accelerated or similar timeframe? (which we have less data for)
g. What regulatory/market conditions must occur for operators to make major maintenance decisions? Do current NSR requirements impact these decisions? What other factors influence decisions not to undertake maintenance or refurbishment of a particular unit?

2. **Panel 2: Equipment and service providers** [50 Minutes] – Objective: To understand the engineering of different classes and ages of boilers and to understand the performance characteristics and ability to operate those systems as non-baseload (cycling) systems.
    a. Are there significant differences in the design, materials, operation, etc. of supercritical and subcritical units that would result in substantially different operational and maintenance patterns and costs?
    b. How is maintenance forecasting done on these units with projections for increased load following and cycling?
    c. How significant is the impact of the quality of coal on maintenance needs with plants switching from CAPP to ILB, for example?
    d. Are there any technologies on the horizon that would enable increased coal plant cycling?
    e. What level of cost is determinative of whether an owner/operator will incur such costs to continue operating a specific unit? Also, are there other issues in addition to costs that determine whether an owner/operator will prolong the life of an existing coal unit?
    f. What other factors might be determinative of whether an owner/operator makes expenditures for continuing the operation of either supercritical or subcritical units?

3. **Panel 3: Government** [50 Minutes] – Challenges with New Source Review in maintenance and operations of existing fleet, and the 111(d) Implications for Fleet Aging
    a. With MATs rule in effect, what is the impact of NSR?
    b. What are the challenges of NSR in the EPA 111(d) proposal?
    c. With respect to NSR and the aging coal fleet, what maintenance can be done with NSR in effect? What could be done if it were not an issue? What would the result be?