Coal-Powered Electric Generating Unit Efficiency and Reliability Dialogue

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Coal-Powered Electric Generating Unit Efficiency and Reliability Dialogue: Summary Report

Prepared for

Office of Advanced Fossil Technology Systems
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U.S. Department of Energy

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Preface

The U.S. Department of Energy (DOE) Office of Advanced Fossil Technologies hosted the *Coal Powered EGU Efficiency and Reliability Dialogue* on September 13, 2017, at the U.S. Energy Association offices in Washington, DC. This dialogue was planned and executed under the direction of Angelos Kokkinos, Director and Dr. Bhima Sastri, Program Manager, at the DOE Office of Advanced Fossil Technology Systems. The information contained herein is based directly on the conversations that took place during the dialogue, which was attended by nearly 30 experts from government, industry, and academia. The contents of this report reflect the expert opinions of the participants; they are not intended to represent the views of the entire coal industry nor those of the U.S. Department of Energy. Similarly, the DOE does not directly endorse any company or technology that is highlighted in this report. Comments and remarks are made without direct attribution to any individual, unless otherwise noted.

Acknowledgments

Many thanks to everyone who participated in the *Coal Powered EGU Efficiency and Reliability Dialogue* on September 13, 2017, at the U.S. Energy Association (USAE) offices in Washington, DC. The presentations and discussions at that event provided the foundation for this report. Special thanks are extended to the speakers (listed below) and to the many expert participants (please see Appendix A for a complete list).

Speakers:

Greg Augspurger, Duke Energy
Mark Bleckinger, Black and Veatch
Dr. Raj Gaikwad, Sargent & Lundy
Tom Hart, AEP
David Helm, Sargent & Lundy
Thomas Higgins, CH2M
Rick Kephart, Emerson
Anand Kulkarni, Siemens Corporation
Anthony Licata, Licata Energy and Environmental Consultants and ASME
Mark Ness, GRE
Russell Noble, Southern Company
Michael W. Smiarowski, Siemens Corporation
Dan Walsh, National Rural Electric Cooperative Association (NRECA)
Karen Whitehead, Black and Veatch
Chuck Zelek, National Energy Technology Laboratory (NETL)

Special thanks are also extended to Heather Greenly, USAE; Susan Maley, Electric Power Research Institute; Karen Whitehead, Black and Veatch; Scott Smouse, DOE; Angelos Kokkinos, DOE; and Bhima Sastri, DOE. Work by Energetics Incorporated was performed under contact LTI-DE-FE0022594.

Acronyms

ABS	Ammonium Bisulfate
BOP	Balance of plant
CAA	Clean Air Act
EGU	Electric generating unit
ELGs	Effluent Limitations Guidelines (and standards)
EPA	U.S. Environmental Protection Agency
FGD	Flue gas desulfurization
HP	Horsepower
LCOE	Least cost of electricity
MW	Megawatt
NETL	National Energy Technology Laboratory
NFPA	National Fire Protection Association
NSR	EPA's New Source Review permitting program to protect air quality
OPC	Operating point control
ROI	Return on investment
SCR	Selective catalytic reduction
VFD	Variable frequency drive

Executive Summary

Coal continues to play a critical role in powering the Nation's electricity generation, especially for baseload power plants. With aging coal generation assets facing decreased performance due to the state of the equipment, and with challenges exacerbated by the current market pressures on the coal sector, there are opportunities to advance early-stage technologies that can retrofit or replace equipment components. These changes will eventually result in significant improvements in plant performance once further developed and deployed by industry. Research and development in areas such as materials, fluid dynamics, fuel properties and preparation characteristics, and a new generation of plant controls can lead to new components and systems that can help improve the efficiency and reliability of coal-fired power plants significantly, allowing these assets to continue to provide baseload power.

Coal stockpiles at electricity generation plants are typically large enough to provide 30 to 60 days of power prior to resupply—significantly enhancing the stability and reliability of the U.S. electricity sector. Falling prices for non-dispatchable renewable energy and mounting environmental regulations, among other factors, have stimulated efforts to improve the efficiency of these coal-fired electric generating units (EGUs). In addition, increased reliance on natural gas and non-dispatchable energy sources has spurred efforts to further increase the *reliability* of coal EGUs.

The *Coal Powered EGU Efficiency and Reliability Dialogue* brought together stakeholders from across the coal EGU industry to discuss methods for improvement. Participants at the event reviewed performance-enhancing innovations in coal EGUs, discussed the potential for data-driven management practices to increase efficiency and reliability, investigated the impacts of regulatory compliance on coal EGU performance, and discussed upcoming challenges for the coal industry. This report documents the key findings and research suggestions discussed at the event.

Discussions at the workshop will aid DOE in developing a set of distinct initiatives that can be pursued by government and industry to realize promising technological pursuits. DOE plans to use the results of the Dialogue coupled with ongoing technical analysis of efficiency opportunities within the coal-fired fleet, and additional studies to develop a comprehensive strategy for capitalizing on thermal efficiency improvements. Expected Power Plant Efficiency Improvements include developing cost-effective, efficient, and reliable technologies for boilers, turbines, and sensors and controls to improve the reliability and efficiency of existing coal-based power plants.

The Office of Fossil Energy at DOE plans to work with industry to develop knowledge pertaining to advanced technologies and systems that industry can subsequently develop. These technologies and systems will increase reliability, add operational flexibility and improve efficiency, thereby providing more robust power generation infrastructure.

The following table lists the research suggestions and questions for further investigation that were identified by participants in each session of the dialogue.

Table ES-1: Summary of Research Suggestions and Inquiries, by Discussion Topic Area

Macro System Improvements
Improving low-load efficiency appears to be a feasible route to achieve significant improvements.
If the space is available, significant energy savings may be achieved by enlarging air heaters to offset problems that arise due to fouling, allowing for heat transfer to be maintained in the presence of ammonium sulfate and bisulfate (ABS) or corrosion. Also the use of sorbents such as hydrated lime can also reduce corrosion and lower exit temperatures.
It is worth exploring the ways existing unit steam turbine generators could potentially be impacted by newer ideas, such as advanced seal design (possible 3% improvement), generator improvement, and hydrogen purity improvements.
Research the use of chemical vapor deposition systems on condenser tubes to improve cleaning, reduce fouling, and enhance heat transfer.
Develop improved materials (e.g., thermoelectrics) to extract energy from the heat in flue gas.
Develop methods for reducing sink temperature to enhance bottoming cycle performance and payback.
Reduce the cost of carbon capture systems, which can be applied in phases to existing units (EOR).
Data Integration and Implications
Facilities might investigate tube leaks to avoid related problems and costs. If a tube leak can be detected prior to an outage, maintenannce can be scheduled for a weekend, when power rates are lower. How many tube leaks might be avoided using acoustic monitoring? In addition, how many forced tube leak outages could be converted to planned tube leak outages due to early detection.?
Increased cycling will increase maintenance, but the direct relationship in unknown. This causality should be explored.
Regulatory Compliance
Initiate a three-way collaboration between DOE, EPA, and industry to improve overall emissions. Conduct the needed research and identify methods to reduce emissions in a practical way.
Further develop and demonstrate technologies for wastewater treatment.
Investigate molecules specifically designed to remove bromine and chlorine from wastewater.
Identify solutions for removing radio nucleotides from water.
Identify methods for treating brine waste streams.
Technology development efforts could focus on mercury capture and emissions, rapid cycling, and methods for responding to load changes.
Upcoming Challenges for Coal EGU and BOP Issues
Blade erosion: It could be useful to look at coatings for these turbines, and understand the conditions under which erosion occurs.

Air seals in air preheaters could be better designed to withstand the effects of cycling.
If boiler tubes are going to be cycled over large temperature ranges, we need to explore the impacts on the magnetite, corrosion rates, and cracking.
There is an opportunity to better understand acoustic vs. ultrasonic sensors and their optimal placement. If a pin leak can be detected at a location, can the propagation of risk be prevented? When the tube breaks, it damages other boiler components nearby. There seem to be early scientific research opportunities for leak detection and sensor placement.

1. Introduction

1.1 Overview and Scope

The existing coal power generating fleet plays a critical role providing reliable on-demand power generation required for power grid stability, and it is important that these existing units can continue to operate in an efficient and reliable manner. The faces many challenges which include:

- Improving plant efficiency through topping cycles, advanced materials, recovery of low grade waste heat, improvements in water usage, lower parasitic losses and the development of advanced sensors, instrumentation, and artificial intelligence control systems based on dynamic data analysis.
- Exploring research opportunities that include building a new knowledge base regarding fuel interactions with plant components such as pulverizers, refractory, steam raising and superheat/reheat surfaces, economizers, and air heaters.
- Developing Artificial Intelligence (AI) systems and other technologies to improve predictive maintenance required to optimize economic and environmental performance and maximize plant reliability.
- Early-stage research on the incorporation of advanced power generation cycles that can be further developed and scaled up by industry to increase plant efficiency or lead to the repowering of existing coal power generation assets.
- Early-stage research on the development and incorporation of advanced monitoring instrumentation, artificial intelligence control systems that maximize plant operating efficiency, minimize unscheduled outages, and provide increased reliability.

The *Coal-Powered EGU Efficiency and Reliability Dialogue* was organized to incorporate these ideas into four key areas.

- **Macro System Improvements:** Specifically, assess advancements in boiler design and operations, steam turbines, and condensers; identify improved heat transfer mechanisms; and discuss the state of advanced environmental controls, materials, and coatings, etc. Topics covered include the EGU condenser, cooling tower, fan improvements, large motor variable frequency drives (VFDs), and cycle isolation (both turbine and boiler).
- **Data Integration and Implications:** Identify key issues and barriers associated with adopting advanced sensors and artificial intelligence; identify the near-term opportunities and benefits of coal-based power generation; and assess the current state of technology and development needs. Discussion topics focused on ways to use sensors, automation, optimization, and modeling to improve coal plant performance, maintenance, and operations.
- **Regulatory Compliance: Energy Efficiency and Reliability:** Identify the impacts of effluent limitation guidelines on energy efficiency; highlight air quality control systems (AQCS), water treatment systems, and evaporation, as well as coal combustion residuals; and discuss New Source Review (NSR) triggers when implementing efficiency improvements.
- **Upcoming Challenges for Coal EGU and Balance-of-Plant (BOP) Issues:** Discuss diverse topics, such as strategies to maintain the competitiveness of coal EGUs in a changing market; the impacts of cycling and advances in boiler design on plant efficiency; BOP issues, such as reduced turbine seal leakage and minimization of super-heater spray; planning for increased pressures on the water energy nexus; ensuring the security of individual plants; and the impacts of robotics.

For each area of discussion, a moderator introduced the topic and outlined the scope. Following the introductory remarks, panelists presented relevant material based on their own experiences or those of their organization. These presentations helped frame the subsequent question and answer (Q&A) sessions and stimulated productive dialogue among the participants and DOE representatives.

1.2 Structure of This Report

This report summarizes and organizes key remarks by the presenters and participants at the event. Chapters 2, 3, 4, and 5 summarize, respectively, points expressed during discussions on the four areas, respectively described above. Each of these chapters records the key points made by the invited speakers, the questions and responses that arose during open discussion, and the topics suggested as potential research areas for DOE. The report appendices provide the agenda and a full list of the participants in attendance. Information marked as confidential or proprietary has been omitted from this document. Presentations from the individual panelists can be obtained by contacting the DOE dialog organizer.

2. Macro System Improvements

Angelos Kokkinos, Director of DOE's Office of Advanced Fossil Technology Systems, introduced the Macro System Improvements portion of the agenda and provided an overview of the topic (scheduled moderator John Marion of EPRI was unable to attend). Mr. Kokkinos encouraged brainstorming and wide-ranging discussions by the participants. The primary focus was on methods and equipment for improving the efficiency of coal-fired power plants.

2.1 Summary of Panel Presentations

The key points made by each presenter or panelist on macro system improvements are summarized in Table 1.

Table 1: Summary of Macro System Improvement Presentations

Name and Affiliation	Presentation Title	Points of Discussion
Dr. Raj Gaikwad, Sargent & Lundy	Efficiency Improvements: Coal-Fired Power Plants	• The EPA Best System for Emissions Reductions (BSER) describes the degree of achievable emissions limitations possible using demonstrated efficiency improvement technologies. • A 2009 Sargent and Lundy report independently investigated the impact of efficiency improvement technologies • The study found that efficiency gains are not additive: impacts were shown to reduce when multiple strategies were deployed in combination. • Many efficiency measures are already widely deployed, including turbine upgrades, intelligent soot-blowers, and variable frequency drives. • Improving low-load efficiency seems to be a feasible route for making significant improvements due to reduction in dispatch of coal EGUs. • Many utilities are already employing best practices.
Russell Noble, Southern Company	Not Provided	• Southern Company has retired a significant number of coal plants in the last decade. • EGU efficiency can be reduced by stack losses, parasitic energy losses, the turbine cycle, and heat rejection. • Southern Company recently partnered with NETL on a paper investigating uses for the low-grade heat rejected from condensers. • Plants are optimized for full-load operation; low loads are the big issue. Capacity factors average 45–50%.

Mark Ness, GRE	Improving Existing Coal Plant Economics	• Coal EGU revenues derive from the sale of power, ancillary services, and byproducts. • The current market price for coal-fired power is below the production cost. • To remain viable, coal plants must sell more ancillary services, reduce fuel costs, reduce reagent and chemical use, produce saleable byproducts, or obtain a regional baseload credit. • Fuel costs account for nearly 70% of the production cost of power. The only ways to reduce fuel costs are to reduce mining costs or decrease heat rates. • Improving boiler efficiency, improving turbine cycle performance, and reducing auxiliary power use are the options available for improving net plant heat rate. • Coal quality and plant cycling can both have negative impacts on plant performance.
Michael W. Smiarowski, Siemens	Coal-Powered EGU Efficiency and Reliability Dialogue	• Four efficiency improvement areas in the steam turbine cycle include: – Steam turbine technology and controls – Condenser optimization – Valves and steam chests – Generators • Five major design features contribute to an overall output improvement: (1) improved interstage shaft sealing; (2) twisted, three-dimensionally shaped drum blades; (3) improved blade profiles; (4) shape of the low-pressure (LP) turbine last stage; and (5) size of the LP turbine last stage. • Plants more than 30 years old will soon need turbine upgrades as most are designed for a 30-year service life. • Condenser operation improvements produce the best results when combined with a LP turbine modification. • Many plants have been able to increase power by tens of MWs, with half of those increases attributed to thermal efficiency improvements.

2.2 Summary of Q&A Session and Open Dialogue

The major points that emerged from the discussion of macro system improvements are summarized in Table 2.

Table 2: Summary of Macro System Improvement Open Discussion Topics

Discussion Point:	**Steam hot-side enhancement: Can we increase the steam temperature on existing units? What are the impediments, and what type of R&D is needed?**
Responses:	Past efforts have investigated burning natural gas upstream, oxy combustion. Other investigations involved cycling 1,000^{0}F exhaust steam from the boiler for upstream heating.
	Tube leaks are the top cause of outages. Boosting steam temperatures can cause the tubes to burst. The carbon steel does not stand up to the higher temperatures.
	Carbon steel tubes would have to be 50% thicker to withstand temperatures 20 degrees higher than the current norm. To go from carbon steel to P91, a plant would need to change many other aspects of the steam line, which would present additional costs. Could be useful to conduct a study on a 250 MW plant.
	The best place to raise the steam temperature is at the turbine, because you can avoid dealing with the steam pipes. You can add a second re-heat, though this is difficult to accomplish at an existing plant.
Discussion Point:	**Most units are running at a 45–65% of load capacity. High excess air is one of the impediments. The National Fire Protection Association (NFPA) recommends maintaining a 30–35% minimum airflow through the boiler. Should we be looking at the combustion flammability issues associated with that minimum and suggest that the NFPA use a lower number?**
Responses:	Make sure that the insurers are in agreement. Any time you make a change, there will be repercussions, whether on the technical side, business side, or insurance side.
	An analysis would require better instrumentation to measure airflow at higher temperatures.
	The addition of SCR and FGD increases the length and volume of the gas patch. Longer purge times may be necessary to fully purge the gas path. This goes against efficiency and reliability. We might benefit from an NFPA review of the underlying philosophy. Maybe we can take advantage of a shutdown purge on a coal unit, or find other approaches to reduce the purge time.
Discussion Point:	**Cycle efficiency: For supercritical units, moving operations from constant to sliding pressure can increase efficiency by about 1%. Could DOE support R&D in this area?**
Responses:	A recent investigation looked at moving an Alstom unit to sliding pressure operation. Such a move would require the unit to spend more time in high-load, low-pressure mode. Few subsystems are optimized for low-pressure operation—they must be reviewed case by case.
	Going from supercritical to natural circulation mode will create issues, but will provide a benefit in subcritical modes, because of the increase in steam temperature. This approach would need to be evaluated on a case-by-case basis.
	Cycling: Turning valves wide open at startup can reduce both start time and the amount of fuel needed for startup. This strategy was explored in the 1980s, but

	little work has been done since then. Jacksonville did it, and some papers from the early 80s are still out there.
Discussion Point:	**Condensers: These units represent the single greatest source of heat loss. Might DOE perform R&D related to improved materials for condensers?**
Responses:	Some plants utilize series condensers. In the winter, you can dry vacuum waste out, but that is not possible in the summer due to limitations on the low-pressure (LP) exhaust area (possibly excluding a short window). The answer may be to store ice from the winter for use in cooling the unit cool in the summer. Can you store cold for the times when you need it?
	Any condenser improvements will impact the turbine significantly, but the benefits will be seen only in the summer. It is unlikely that a new metal will be invented, so it makes sense to focus on enhancing the heat transfer to the atmosphere, from the cooling tower.
	MIT just did some work on super hydrophobic coatings on condensers. The coatings boosted condenser efficiency by 0.5%. A few years ago, another study examined optimized condenser cleaning. Plants were losing up to $1M/ year from poor maintenance. Improvements are possible using online condenser cleaning techniques. It may be helpful to research the use of chemical vapor deposition systems on the tubes.
	Ammonia-based scrubbers represent another viable option for reducing emissions, while also providing a saleable byproduct. The revenue increase from using ammonia-based scrubbers is equivalent to a 5–10% increase in heat rate on the plant dispatch.
Discussion Point:	**To improve macro system efficiency, is there a role for controls, control operations, or fans in the condenser?**
Responses:	VFDs on fans have been shown to increase efficiency. Fan speeds should change daily, based on the surface temperature of the cooling source.
	There seems to be an emphasis on putting new technologies into old systems. There are other opportunities for innovation, instead of trying to shoehorn new fixes into old systems.
	Opportunities with CHP (combined heat and power) need to be investigated.
	Better materials are needed (perhaps thermoelectrics) to extract heat from the flue gas.

2.3 Summary of Research Suggestions

The workshop participants explicitly suggested several topics for DOE research and identified additional topics that industry has not yet fully explored or resolved. All of these topics are summarized in Table 3.

Table 3: Summary of Macro System Improvement Research Suggestions

Improve low-load efficiency. It seems to be a feasible route for achieving significant improvements.
Enlarge air heaters to offset ammonium sulfate and bisulfate (ABS) or corrosion problems and improve efficiency—but only if space is available for the larger physical footprint; it could result in significant energy savings. Better coatings on the air heater basket material may make it easier to remove the ABS deposits.
Explore the potential impacts of newer ideas on existing unit steam turbine generators, such as advanced seal design (possible 3% improvement), generator improvement, and hydrogen purity improvements.
Research the use of chemical vapor deposition coating systems on condenser tubes to reduce fouling, improve cleaning, and overall heat transfer.
Develop improved materials (e.g., thermoelectrics) to extract the heat from flue gas.
Develop methods for improving cooling systems that reduce sink temperature to enhance bottoming cycle performance and payback.
Reduced cost of carbon capture systems which can be applied in phases to existing units (EOR)

3. Data Integration and Implications

The discussion on data integration and implications focused on ways to use sensors, automation, optimization, and modeling to improve coal plant performance, maintenance, and operations. Susan Maley of EPRI provided the following position points during her introductory remarks to stimulate discussion:

- Data is a commodity with value; information has a higher value than data.
- Evolution, not revolution, is needed to improve coal EGUs.
- Improvement potential has been publicized, but the benefits have been slow to surface.
- We need to collaborate; get the subject matter experts together.
- The EPRI I4Gen Survey produced useful insights and serves as a useful reference for RD&D recommendations.
- Effective data utilization requires a platform for data collection, more sensors, and a plan detailing which measurements are of greatest value.
- New approaches are needed to effectively communicate or display data and information.
- Plants need guides and how-to information; the operations personnel involved typically do not possess an IT background.
- All steps lead to enhancing plant reliability in the face of flexible operations.

3.1 Summary of Panel Presentations

The key points made by each presenter or panelist regarding data integration and implications are summarized in Table 4.

Table 4: Summary of Data Integration and Implications Topic Area Presentations

Name and Affiliation	Presentation Title	Points of Discussion
Greg Augspurger, Duke Energy	The People Are Gone; All We Have Left Is Data	• Duke Energy has a well-established Maintenance and Diagnostic (M&D) Center to monitor Fossil and Hydro assets. • M&D is replacing manual “rounds,” but the rapid growth exceeds available resources. • Better analytics would screen false positives, diagnose potential causes of failure, and estimate remaining useful life. • There are several approaches to advanced analytics, but a clear path for utilities has not been demonstrated. • Moving data to advanced analytics applications is an issue. • How do we optimize the infrastructure for advanced analytics systems?

Rick Kephart, Emerson Automation Solutions	Coal Powered EGU Efficiency and Reliability	• Changing generation profiles reflect the increased demands being placed on coal EGUs. • Advanced Control • Optimization • Simulation • Prognostics • Human Factors

3.2 Summary of Q&A Session and Open Dialogue

The major points that emerged during the discussion of Data Integration are summarized in Table 5.

Table 5: Summary of Data Integration and Implications Open Discussion Topics

Discussion Point:	**Cost recovery for plant optimization and heat rate recovery projects**
Responses:	Given that these plants will likely be retired in about 20 years, it would be difficult to convince anyone to invest a significant amount into data management for the purpose of plant optimization or heat rate improvement. By the time the R&D is completed, the units will not continue operating long enough to recoup the investment. Nonetheless, this data-driven approach is the right direction to pursue. Data management can help avoid environmental fines, avoid capital costs, and inform or target spending (e.g., How do I keep this plant running longer with no additional CAPEX)?
Discussion Point:	**Addressing the underlying chemistry in plant dynamics**
Responses:	In addition to focusing on the mechanical side, it is important to look at the chemistry. Multi-variable analysis is key. We surveyed our operators on the cycle chemistry, and more than 40% do not trust their monitors because the chemists are always working on them.
	Downstream processes can snowball. Beware of unintended consequences from upstream changes because everything is interrelated. Use care in the selection of tools and their application.

Discussion Point:	**Alternative goals for data-driven analysis**
Responses:	It is necessary to look at the overall plant. What are the best levels at which to run precipitate scrubbers? How can we recover the type of gypsum that our customers want to purchase? According to NETL, a product like this does not yet exist. Each plant could optimize for their location. It would be of benefit to lower your LCOE. The work presented represents a great start, but a few more steps are required.
	To avoid problems and costs, it is worthwhile to investigate tube leaks. How many tube leaks could be detected early with acoustic monitoring? If we can see a tube leak before an outage, we can schedule an outage during the weekend, when power rates are lower.
	Everyone knows that if you cycle more, maintenance will increase, but no one knows the direct relationship. This causality should be explored so costs can better reflect reality.
Discussion Point:	**What role can data analytics and plant modeling play in predicting failures, improving heat rate, or reducing emissions?**
Responses:	Data analytics plays a role in day-to-day operations. Site-specific information is another concern. Can a common model be developed? Perhaps it is possible to form a consortium or a commercial product.
	No plant is the same as another; nothing runs the same (e.g., interactions, conditions, etc.). Data from one plant is typically not applicable to another, though it can be helpful. It is more beneficial to develop an approach that can be replicated. Do we have a data analytics approach that can take the big data approach and apply it? Can one analytic approach be developed and proven for everyone? Can we identify the key chemistry issues?
	Learn from operators to inform new plant designs. There is a tendency to see power plants as a bunch of blocks (functional). You can wind up with blocks that cannot talk to each other. The field could benefit from a hybrid approach—wherein models build from first principles but can be adjusted. These models can then be updated with plant data.
	With regard to plant modeling, one must start with the base design because many factors can change. For instance, the plant may have been designed for a particular type of well water, but now it uses river water. Or perhaps it was designed for industrial-grade ammonia and now uses urea from the agricultural industry. The original design specs are needed for reference. These things need to be documented and incorporated into the model.
Discussion Point:	**Is there an ideal plant out there, in the computer models?**
Responses:	State of the art? Yes. A standard design? No.
	In designing a new plant, the budget requires a bare bones approach. It is typical to start with a cut and paste, and then minimize the budget however possible. It's not that the technology isn't available; the real limitation is the time and budget requirements, especially as related to architecture and engineering (A&E) costs.

Discussion Point:	**In other countries, like China, they are building state-of-the-art chemical plants. Does that put us at a disadvantage?**
Responses:	China has many coal-to-liquids and coal-to-gas plants.
	In this country, we need a return on investment (ROI) in a few months to years.
	Utility commission rate recovery is another factor. Can you justify an investment on a plant that only has 10 years until decommissioning?
Discussion Point:	**How do you integrate all of the electronic data on the plant, with the observations that the operator makes?**
Responses:	At some point, the operator must get up, find the maintenance person, and say "Here's what I'm seeing." We eventually had to get plant managers and equipment managers together, sit them down, and make them listen. Prior to establishing collaboration on this level, everyone has a tendency to blame issues on others in different areas of the plant.

3.3 Summary of Research Suggestions

The workshop participants explicitly suggested several topics for DOE research and identified additional topics that industry has not yet fully explored or resolved regarding coal EGU improvements related to sensors, controls, monitoring, and data integration. These topics are shown in Table 6.

Table 6: Summary of Data Integration and Implications Research Suggestions

If a facility has specific problems or costs that it wants to avoid, it should investigate the cost of tube leaks. How many tube leaks could you detect early using acoustic monitoring? If a tube leak can be detected before an outage, a planned outage can be scheduled during the weekend, when power rates are lower.
Increased cycling will increase maintenance, but nobody knows the direct relationship. This causality should be explored.

4. Regulatory Compliance: Energy Efficiency & Reliability

This session explored issues related to coal-fired power generation facility compliance with air and water regulations and the associated impacts on plant energy efficiency and reliability. Angelos Kokkinos, from the DOE, provided the following position points during his introductory remarks to stimulate discussion:

- Energy efficiency and reliability are impacted by air quality control systems (AQCS).
- Performance can be improved by replacing older systems with low draft loss systems.
- Variable frequency drives or two-speed motors on large equipment can increase energy efficiency.
- Operating plan for load cycling / low load conditions to minimize operating equipment
- Use of organic additives to reduce WFGD absorber operating spray levels
- Optimize WFGD oxidation air systems and byproduct
- Flue gas heat recovery for evaporation of WFGD wastewater
- Use of dry FGD systems without FGD wastewater stream

4.1 Summary of Panel Presentations

The key points made by each presenter or panelist during the session on regulatory compliance (and its impacts on energy efficiency and reliability) are summarized in Table 7.

Table 7: Summary of Regulatory Compliance Topic Area Presentations

Name and Affiliation	Presentation Title	Points of Discussion
Anthony Licata, Licata Energy & Environmental Consultants and ASME	NSR Impacts	• To implement energy efficiency and reliability projects on existing EGUs, there needs to be a legislative change to the current New Source Review (NSR) rule. • It would be beneficial to provide an exemption for energy efficiency and reliability projects. • NSR is triggered for an existing unit when a physical modification or change in method of operation results in an actual or potential net emission increase over the EPA established significance levels. • Some plant improvements significantly reduce emissions in one area in exchange for a slight increase in a different kind of emission. Still, this can trigger NSR, and impede the possibility of upgrades. • Routine maintenance, repair, and replacement activities do not trigger NSR, though the meaning of 'routine' is not well defined. • Efficiency improvements have been known to trigger NSR in the past.

		• Since the year 2000, there has been a drastic increase in the number of utility consent decrees for NSR violations; on the order of $18.9 billion in settlements.
Anthony Licata, Licata Energy & Environmental Consultants and ASME	Heat Rate	• DOE/EIA and EPA use different methods for calculating annual heat rates for power plants. • DOE/EIA also reports as tested heat rates. • EPA and DOE/EIA data are in conflict • Heat rate measurements are an important factor in plant economics, energy efficiency and calculating emissions. • Industry needs to have DOE and EPA working on a compatible basis.
Thomas Hart, AEP	Not Provided	• EPA Effluent Limitation Guidelines (ELG) are regulations governing the release of mercury, arsenic, and biological contaminants in surface water discharged from EGUs. • Pilot tests are being conducted to test the relative effectiveness of thermal and biological effluent treatment methods. • More auxiliary power is required for thermal treatment, but biological treatment has higher capital costs. • Any capital-intensive investment must be recovered within the expected lifetime of the plant. • The EPA's voluntary incentive plan for direct dischargers extends the compliance timeline for facilities that agree to install vapor compression evaporation systems to treat FGD wastewaters. • However, the limits become tougher after the compliance timeline ends, and it is unclear if technologies are even available to meet the stricter requirements. • Pilot tests for efficacy must be done for four to six months, to capture the seasonal variations in biological activity in the bodies of water used for discharging effluent. If the testing period is not long enough to capture variations, the resulting data will not be robust enough to draw meaningful conclusions from. • Water testing can be difficult, because it takes two weeks to accurately determine what is in the water. By the time the results are available, the weather, plant load levels, and water temperatures have all changed, which means the water quality is no longer the same as it was when the test samples were taken. • EPRI, and a private firm named Wet Chemistry, have investigated instrumentation. But as of yet, no commercial products offer a high enough resolution to enable high system performance. • Daily measurements, and the calculation of a 90-day rolling average, could be a short-term workaround for measuring contaminant levels.

		• Technology development efforts need to focus on mercury capture and emissions, rapid cycling, and methods for responding to load changes. • Appropriate instrumentation needs to get to the commercialization; plants are currently "driving through the rear-view mirror".
Mark Bleckinger, Black and Veatch	Regulatory Compliance: Energy Efficiency and Reliability	• Fabric filters, used for particulate control, require cleaning, and typically use high pressure pulse jets for cleaning. Suppliers are starting to develop lower pressure systems utilizing higher volumes of air. • Intermittent energization can improve the performance of precipitator rapping systems. Benefit can be derived from shutting down some fields periodically, as opposed to running all fields at all times. • Water usage reduction, and process optimization strategies can improve the performance of Flue-Gas Desulfurization (FGD) systems. • Catalyst cleaning and design, direct injection of aqueous ammonia, and system tuning can improve the energy efficiency of selective catalytic reduction (SCR) systems. • Overall air quality control system design can be improved through the design of draft systems, and through improved control of tramp air.
David Helm, Sargent & Lundy	NSR Triggers When Implementing Efficiency Improvements	• NSR uncertainty could be a disincentive for efficiency improvement projects. • Under current regulations, NSR can be avoided if projected emissions increases are related to demand increases (i.e., not project-related); however, EPA may scrutinize such attributions. • Other options to alleviate NSR uncertainty include amending the Clean Air Act (CAA) to exclude efficiency and reliability improvements from NSR requirements and EPA rulemaking to eliminate NSR concerns for efficiency and reliability improvement projects.

4.2 Summary of Q&A Session and Open Dialogue

The major points that emerged during the discussion of regulatory compliance issues are summarized in Table 8.

Table 8: Summary of Regulatory Compliance Open Discussion Topics

Discussion Point:	**Exploring contaminant issues**
Responses:	What conditions are creating the organo-contaminants upstream? What upstream species are responsible for converting contaminants to the insoluble form? The scrubber is a chemical soup. Thirty years ago, we designed it for removing

	nitrogen dioxide (NO_2), then for sulfur dioxide (SO_2) and other stuff. We're trying to do a whole lot. A lot of junk is crammed into the absorber vessel.
	Looking at alkaline injection upstream of the precipitator and other places. Trying to figure out where it works. We're looking at how to get the SO_3 out first. How do I protect the air heater when I want to get to lower loads? Looked at ELG process: taking brine, flashing it, …. That 280^0 gas will get scrubbed quickly. The scrubber doesn't care if you're going in at 280^0 or 350^0. Another factor that needs to be monitored when operating at low load is water usage. Every time you stop pushing slurry forward, you are flushing water back, which causes the water to increase. At high load, you wouldn't see the increase.
	Fractionalization of coal: Only have enough money for a pilot test, but at 5% micronization, we should be able to remove all gasses. Installing some condensing heat exchangers could improve the heat rate. The condensors could then be made of carbon or stainless steel. Tests will be conducted soon.
	One company has been testing a salt-like meter, for salt-like control, which reduces the NO_x and produces selenite instead of selenate. Also, a high pressure reverse osmosis system removes all of the contaminants. Another issue that has been uncovered: operators need to keep the water levels down as low as possible.
	EPA funded scientific research at the University of North Dakota to examine the toxicity of selenium and mercury. These elements combine with each other to produce a non-toxic selenium-mercury compound, but the agency decided not to change the regulations. The research concluded that the majority of the soil in the United States is actually selenium deficient. Everything that's biological requires selenium.
	Is it possible to accomplish selenium removal via membranes?
	Brine waste streams all have to be treated. We're following companies in China and San Franciso that are both trying it. There is uncertainty as to whether these small companies can succeed commercially. If they perform an installation and the technology does not work, can small companies hang on for two or three years to resolve it? NJIT is doing nanopore work. Ohio State is doing membrane research. Making the transition from the lab at a university to the pilot scale is a huge jump.
Discussion Point:	**Use of bromine and its impacts**
Responses:	We inject bromine at our facility for mercury control, and it is now being picked up in the wastewater treatment plants. There are states that are regulating bromine now; it is in state water purification standards.
	Even just 1 ppm of bromine can cause lethal contaminants in public water. If you have a choice between bromine and other options for mercury control, avoid bromine.
	To get rid of bromine, it must be evaporated, which yields a salt that goes to the landfill. If the biolgoicals cannot get the bromine and chlorine out, it may be time to look at specific molecules designed to remove bromine and chlorine. In fact, you never get rid of it; you just move it around. We just encapsulate the molecules and put them in the landfill. How does one get radio nucleotides out of water?

Discussion Point:	**Is it critically important to have good process chemistry monitoring and analysis and to understand the impacts of the reaction kinetics? Wouldn't it be ideal to know what is happening up front—instead of after a violation?**
Responses:	Make the unit as efficient as possible and get the flue gas as low as possible to minimize the amount of pollutants that must be addressed. When the coal is dried up front, it removes 30% of the mercury. Then, optimize the combustion process. Many plants release more flue gas than necessary.
	The problem is cycling. At low load, the plant does not operate at that sweetspot, and flue gas production varies with the plant operating point.

4.3 Summary of Research Suggestions

The workshop participants explicitly suggested several topics for DOE research and identified additional topics that industry has not yet fully explored or resolved regarding coal EGU regulatory compliance with air and water regulations and the associated impacts on plant efficiency and reliability. These topics are summarized in Table 9.

Table 9: Summary of Regulatory Compliance Research Suggestions

What can DOE do to assist coal-powered facilities with compliance issues? Initiate a three-way collaboration between DOE, EPA, and industry to improve overall emissions. Conduct the needed research and identify methods to reduce emissions in a practical way.
Upstream of FGD wastewater Treatment: • Improve NOx control reliability (nitrates) • Further develop sulfite control to reduce selenium oxidation • Further test the efficacy of adding iron to FGD Scrubbers to treat Se, As and Hg • Further study the use of lime to mitigate SO_3 and its impact on reducing Cl and FGD wastewater flow Wastewater Treatment • Demonstrate advanced ZLD technologies (such as COLD, Bulldozer evaporation systems) • Demonstrate membrane biological treatment and passive biological treatment • Investigate why soluble arsenic is difficult to remove
To get rid of bromine today, it must be evaporated, and the resulting salt goes to the landfill. If biolgoicals cannot eliminate the bromine and chlorine, is it time to look at specific molecules designed to remove bromine and chlorine?
Explore methods for removing radio nucleotides from water.
Brine waste streams all need to be treated. How is it done?
Technology development efforts need to focus on mercury capture and emissions, rapid cycling, and methods for responding to load changes.

5. Upcoming Challenges for Coal EGU and Balance of Plant Issues

Discussions of the upcoming challenges for coal EGU and BOP issues cover a range of topics related to maintaining the competitiveness of coal EGUs in a changing market. Karen Whitehead of Black & Veatch moderated the session and primed the discussion by addressing the following key points:

- What is load cycling?
- Types of startup conditions: cold start, warm start, hot start
- Cycling operation: cycling causes greater stress than static conditions
- When we talk about cycling operation, we are concerned about fatigue, creep, and metal overheating. Fatigue leads to failure after a number of cycles, creep reduces material life, and metal overheating occurs when metal components are exposed for prolonged periods to temperatures that exceed their design specifications.
- Units are designed with a finite service life; every cycle uses up some of that life. If we ask a baseload unit to cycle, we use up that life more quickly.
- Base loaded units will use up the least amount of that life.
- Reasons for cycling: more load-following operations due to renewables and automatic generation control. We are already seeing this; it is not a projection.
- Cycling impacts: Steam drum connections; connections to the nozzles are thinner-walled components compared to the steam drum, which causes differential heating stress on the components and econmoizer inlet header fatigue (due to temperature mismatch).
- Plants are looking at ways to operate at minimum load or to reduce their minimum sustainable load.
- In summary, if you start cycling a baseload unit, you will consume the useful life at a faster rate. You can minmnimize damage by revising O&M practices, more frequent inspections, additional instrumentation, and modified startup/shutdown procedures.

5.1 Summary of Panel Presentations

The key points made by each presenter/panelist during the discussion of upcoming challenges are summarized in Table 10.

Table 10: Summary of the Upcoming Challenges Topic Area Presentations

Name and Affiliation	Presentation Title	Points of Discussion
Chuck Zelek, NETL	Market Considerations for Efficiency Improvements at Coal-Powered EGUs	• NETL has a long history of assessing EGU efficiency improvements. • The utility market has changed significantly since 2010. • Can efficiency improvements make economic sense for coal-powered EGUs in current markets?

		• Heat rate improvements can help to improve the dispatch position of an existing coal-powered EGU and can also serve as a hedge against changing gas prices.
Anand Kulkarni, Siemens	Efficiency and Reliability Dialogue	• Multiple approaches are available to increase the efficiency/reliability of coal-fired power plants (e.g., minimization of exhaust gas loss, utilization of exhaust heat for heating condensate/feed water, etc.). • New power systems are going to face many challenges owing to a wider range of fuels with higher contaminant levels and higher component operating temperatures. • There is a growing need for improved materials for supercritical steam conditions. Common materials challenges for similar damage mechanisms with gas turbines should be identified. • Synergy is needed to address materials issues/design curves across multiple frameworks (boilers/steam and gas turbines). • Creating an atlas of microstructures for common materials and their service experience in multiple environments (temperature/pressure) will help to expand/extrapolate materials risks to novel conditions. • Novel manufacturing approaches (e.g. Additive manufacturing) can be utilized for topology optimization of parts to address baseload vs cyclic operations of coal power plants. • Plant-level modelling efforts can aid with location-specific risks/mitigation measures to ensure reliable operation of power plants.
Dan Walsh, NRECA	Impact of Cyclic Operations on the Generation Fleet	• Eventually there will be a significant increase in plant outages, replacement power costs, and O&M budgets. These increases will occur in 7–24 months for older fossil units and in about seven years for new fossil plants. • An increase in plant starts—to beyond 50 per year (one start per week)—can increase boiler tube failures by a factor of four. • Reliability has been shown to decrease by 15% to 25% with dramatic increase in replacement power costs over the life of a plant. • O&M budgets have increased by 5 to 10% per year directly in annual maintenance and capital budgets for repair.
Grant Rommell, NETL	Funding Opportunity Announcements	• Understanding the toolbox for funding opportunity announcements (FOAs) • Understanding how to work with NETL • NETL's annual FOA process flow • Overview of the financial assistance process

5.2 Summary of Q&A Session and Open Dialogue

The major discussion points that emerged during the conversation on upcoming challenges for coal EGU's are summarized in Table 11.

Table 11: Summary of Open Discussion Topics Related to Upcoming Coal EGU Challenges

Discussion Point:	**Is there enough data at DOE to understand the piece of the market where DOE adds value?**
Responses:	While there are some numbers, we need to show the value of research to justify the investment. We may need to develop a model that includes the quantified cost to society.
	Inertia, guaranteed fuel, etc. These are services that we provide that we aren't currently getting paid for. A market does not effectively exist for these qualities, but the qualities differentiate coal generation from other generating sources.
	Coal adds value because it is always there. Renewables and other intermittent power resources cannot say that, and the fluctuating ramp rates are an issue.
	Even the gas units cannot be 100% reliable as firm gas contracts can be difficult to obtain. Even pipelines can fail with no fuel storage on site.
Discussion Point:	**R&D needs to address cycling impacts on balance of plant.**
Responses:	A nine-year overhaul at one facility showed significant erosion on the intermediate pressure (IP) blades. That stage saw erosion when other stages did not. Why? Magnetite layers started coming off. Research could look at coatings for these turbines. Under what conditions would a certain band of coatings release magnetite layers?
Discussion Point:	**Seals**
Responses:	Air heater seals: with cycling, air heater seals offer little reliability. Hot spots develop and are hard to eliminate.
	The variable clearance seals were working well for 10 years, until we began cycling.
	Materials for seals: what are they made of?
Discussion Point:	**Cycling and Reliability**
Responses:	Many of the studies neglect cycling in their models. Cycling is somewhat of a recent phenomenon that has not been accounted for in the modeling.
	At least one software vendor has a software package that can calculate the existing lifetime of gas turbine components, but there does not seem to be an equivalent package on the coal side.[1]
	At a recent meeting, one company said that they had similar tools for projecting failure, but it was more combustion turbine centered than coal fleet.
Discussion Point:	**Predicting tube failures: Investigating circulation issues, water chemistry; inside and outside of tubes; welds, attachments.**

Responses:	Ongoing efforts within the Air Force are working to address this issue. A case study was published. They changed their load cycling, modified the shape and area a bit, and then the same part could be used for cycling conditions. Manufacturing can address some dire needs.
	EPRI has been doing work on tube failure for a long time, though there may be some areas that they are not addressing. They have not really looked at what happens when you cycle boiler tubes over a certain temperature range: what will happen to the magnetite, to corrosion rates, cracking. These phenomena have not been explored under the large temperature ranges induced by cycling.
	The rate and occurrence of tube failures depends on many factors present at the site, including: salt, moisture, Sulphur.
	Investigate high temperature pH: A host of corrosion sensing options exist, but they have to be specifically matched to the type of corrosion present. It is not possible to prevent all boiler system leaks. There is a lot of existing science on the detection and location of early leaks. There is an opportunity to better understand acoustic vs ultrasonic sensors and where to place them. If you can detect a pin leak at a location, can you prevent the propagation of risk? When the tube breaks, it damages nearby equipment. There seem to be early scientific research opportunities for methods to detect leaks and optimally place the sensors.
	Thermal management: when you get better at managing heat in your boiler, your corrosion rates become predictable. If you had constant temperature, everything would be predictable.
	DC coronas have been shown to reduce back pressure, though the mechanism is still not well understood. There are reports available, DC coronas are cheap to make, and they have the effect of improving heat rate.[2]
	Operational changes: sometimes when tube leaks are identified, the plants are still required to run for an extra day before they can be shut down.
Discussion Point:	**Coal/ Gas Hybrids**
Responses:	There was a DOE program back in the 1970s on direct injection of coal into gas turbines.
	Radiant reheater: coal and natural gas hybrids.
Discussion Point:	**Additional value streams**
Responses:	Recover CO_2 and use it in other valuable markets
	Syngas production to enhance income. Make methanol in the evening. In the daytime, take the syngas and pump it into the boiler.
	Polygeneration units: units that can make both power and chemicals, when needed.

[1] One commenter suggested that this technology has been developed by ABB and Alstom and thinks that Structural Integrity Inc. may also offer this service.

[2] The idea of DC coronas was questioned by one reviewer that suggested it needs to be proven or ignored. Discussion on DC coronas was non-specific and did not mention what back pressure was reduced or if the heat rate improvement was on the air-flue gas system or the steam-water system.

5.3 Summary of Research Suggestions

Table 12 summarizes direct research suggestions made by the workshop participants as well as other topics introduced by the participants that have not been resolved within the industry regarding upcoming challenges for coal EGU's and the balance of plant issues.

Table 12: Summary of Research Suggestions Related to Upcoming Challenges

Blade erosion: It could be useful to look at coatings for these turbines. Under what conditions would a certain band of coatings release magnetite layers? Could be a research issue.
Explore better designs for air preheater air seals that will help them hold up to cycling.
If boiler tubes are cycled over a certain temperature range, what is going to happen to the magnetite and steam-side oxidation, or to gas-side corrosion rates, and to tube cracking? These impacts have not been explored across the large temperature ranges induced by cycling.
There is an opportunity to better understand acoustic vs. ultrasonic sensors, and where to place them. If a pin leak can be detected at a location, can the propagation of risk be prevented? When the tube breaks, it damages other boiler components nearby. There seem to be early scientific research opportunities for leak detection and sensor placement.

6. Next Steps and Future Work

The discussions at this workshop will serve as an input that DOE considers in developing future initiatives that can be pursued by both government and industry. This workshop generated research strategies that can be further developed through analysis, and collaboration.

The Office of Fossil Energy at DOE plans to work with industry to develop knowledge pertaining to advanced technologies and systems that industry can subsequently develop. These technologies and systems will increase reliability, add operational flexibility and improve efficiency, thereby providing more robust power generation infrastructure.

DOE plans to use the results of the Dialogue coupled with ongoing technical analysis of efficiency opportunities within the coal-fired fleet, and additional studies to develop a comprehensive strategy for capitalizing on thermal efficiency improvements. Expected Power Plant Efficiency Improvements include developing cost-effective, efficient, and reliable technologies for boilers, turbines, and sensors and controls to improve the reliability and efficiency of existing coal-based power plants.

Appendix A: Participants and Workshop Agenda

Table 13: List of Dialogue Participants

First Name	Affiliation
Greg Augspurger	Duke Energy
Mark Bleckinger	Black & Veatch
Craig Bleth	Minnkota Power Cooperative
Doug Carter	LTI, Inc.
Brad Chadwell	Energetics Incorporated
Victor Cervino	Mitsubishi Hitachi Power Systems Americas, Inc.
Ed Chichanowitcz	J.E. Chichanowitcz, Inc.
David Farnsworth	Great River Energy
Raj Gaikwad	Sargent & Lundy
Heather Greenly	U.S. Energy Association
Tom Hart	American Electric Power Service Corporation
David Helm	Sargent & Lundy
Thomas Higgins	CH2M
John Hutchinson	Electric Power Research Institute
Ayaka Jones	U.S. Department of Energy
Richard Kephart	Emerson Power and Water Solutions
Angelos Kokkinos	U.S. Department of Energy
Holly Krutka	Peabody Energy
Anand Kulkarni	Siemens Corporation
Amishi Kumar	ORISE
Robie Lewis	U.S. Department of Energy
Anthony Licata	Licata Energy and Environmental Consultants, Inc. & ASME
Susan Maley	EPRI
Jim Marchetti	James Marchetti, Inc.
John Marion	Electric Power Research Institute
Nancy Mohn	Independent Owner
Riley Moore	Tri-State G&T
David Muraskin	LTI, Inc.
Mark Ness	Great River Energy
Russell Noble	Southern Company
Gerry Pfau	Minnkota Power Corporation
Bhima Sastri	U.S. Department of Energy
Harry Schwartz	Energetics Incorporated
Mark Shilling	San Miguel Electric Cooperatives, Inc.

Scott Smouse	U.S. Department of Energy
Emmanuel Taylor	Energetics Incorporated
Kevin Toupin	Riley Power Inc.
Peter Tsirigotis	US EPA
Daniel Walsh	National Rural Electric Cooperative Association
Karen Whitehead	Black and Veatch
Chuck Zelek	NETL

Agenda

Wednesday, September 13, 2017

Topic: This dialogue will explore a broad range of technical developments in coal efficiency and reliability, including a background on existing R&D materials and progress, macro system improvements, data integration, regulatory compliance, and upcoming challenges for coal EGU and balance of plant issues.

Hosts:	**Angelos Kokkinos** **Director,** Office of Advanced Fossil Technology Systems U.S. Department of Energy
Location:	**U.S. Energy Association** **1300 Pennsylvania Ave. NW Suite 550, Washington, D.C. 20004**
Time:	8:00 am – 5:00 pm
Registration:	Please email your RSVP to Heather Greenly, Program Coordinator, United States Energy Association hgreenley@usea.org
Attire:	Business Casual
Contacts:	**Heather Greenly**, Program Coordinator, United States Energy Association hgreenley@usea.org, (202) 312-1257
Wi-Fi:	Network and username will be posted at the event.

7:45 am **Registration check-in**

8:00 am **Welcome and Opening Remarks**

Angelos Kokkinos
Director, Office of Advanced Fossil Technology Systems
U.S. Department of Energy

8:10 a.m. **Briefing: Goals and objectives of meeting**
This briefing will describe the background on existing R&D materials, recent thrusts and new developments, as well as the overall direction at the Department of Energy in considering EGU efficiency and reliability. The critical role of advancing research in this area and the need for a national initiative around accelerating such technologies will be highlighted.

8:30 am **Legal considerations: Dr. Bhima Sastri**

8:35 am **Session 1: Macro System Improvements**
Topics will include the condenser, cooling tower, fan improvements, large motor VFDs, cycle isolation (both turbine and boiler).

Objectives:

- Assess advancements in boiler designs, steam turbines, condensers
- Identify improved heat transfer mechanisms
- Discuss the state of advanced environmental controls, materials, coatings, etc.

Moderator: John Marion, EPRI

Panelists: **Dr. Raj Gaikwad,** Sargent & Lundy
Russell Noble, Southern Company
Mark Ness, GRE
Michael W. Smiarowski, Siemens

10:00 am **Coffee Break**

10:20 am **Session 2: Data Integration and Implications**
This session will focus on how **s**ensors, automation, optimization, and modeling can be used to improve coal plant performance, maintenance, and operations.

Objectives:

- Identify key issues and barriers associated with adopting advanced sensor and intelligence technologies
- Identify the near-term opportunities and benefits for coal-based power generation
- Assess the current state of technology and development needs.

Moderator: Susan Maley, EPRI

Panelists: **Greg Augspurger**, Duke Energy
Rick Kephart, Emerson

12:00 pm **Lunch on your own + networking**

1:00 pm **Session 3: Regulatory Compliance: Energy Efficiency & Reliability**
This discussion will cover compliance with air and water regulations for coal-fired power generation facilities and the associated impacts on power plant energy efficiency.

Objectives:

- Identify the impact of effluent limitation guideline compliance on energy efficiency
- Highlight air quality control systems, water treatment systems, evaporation, and coal combustion residuals
- Identify New Source Review triggers when implementing efficiency improvements

Moderator: **Angelos Kokkinos, DOE**

Panelists:
Tom Hart, AEP
Thomas Higgins, CH2M
Mark Bleckinger, Black and Veatch
David Helm, Sargent & Lundy
Anthony Licata Licata Energy

2:30 pm **Coffee Break and Networking**

3:00 pm **Session 4: Upcoming Challenges for Coal EGU and Balance of Plant Issues**

- Maintaining the competitiveness of coal EGUs in a changing market
- Cycling impacts to boilers and advances in boiler designs
- BOP issues, such as reduced turbine seal leakage and minimization of super-heater spray
- Planning for increased water/energy nexus pressures
- Ensuring security of individual plants
- Impact of robotics.

Moderator: Karen Whitehead – Black and Veatch
Chuck Zelek, NETL
Anand Kulkarni, Siemens
Dan Walsh, NRECA

4:15 pm **The Path Forward and Meeting Review, Discussion**
Scott Smouse/Bhima Sastri, DOE

4:45 PM **Conclude**
Focus group survey

5:00 pm **Close**