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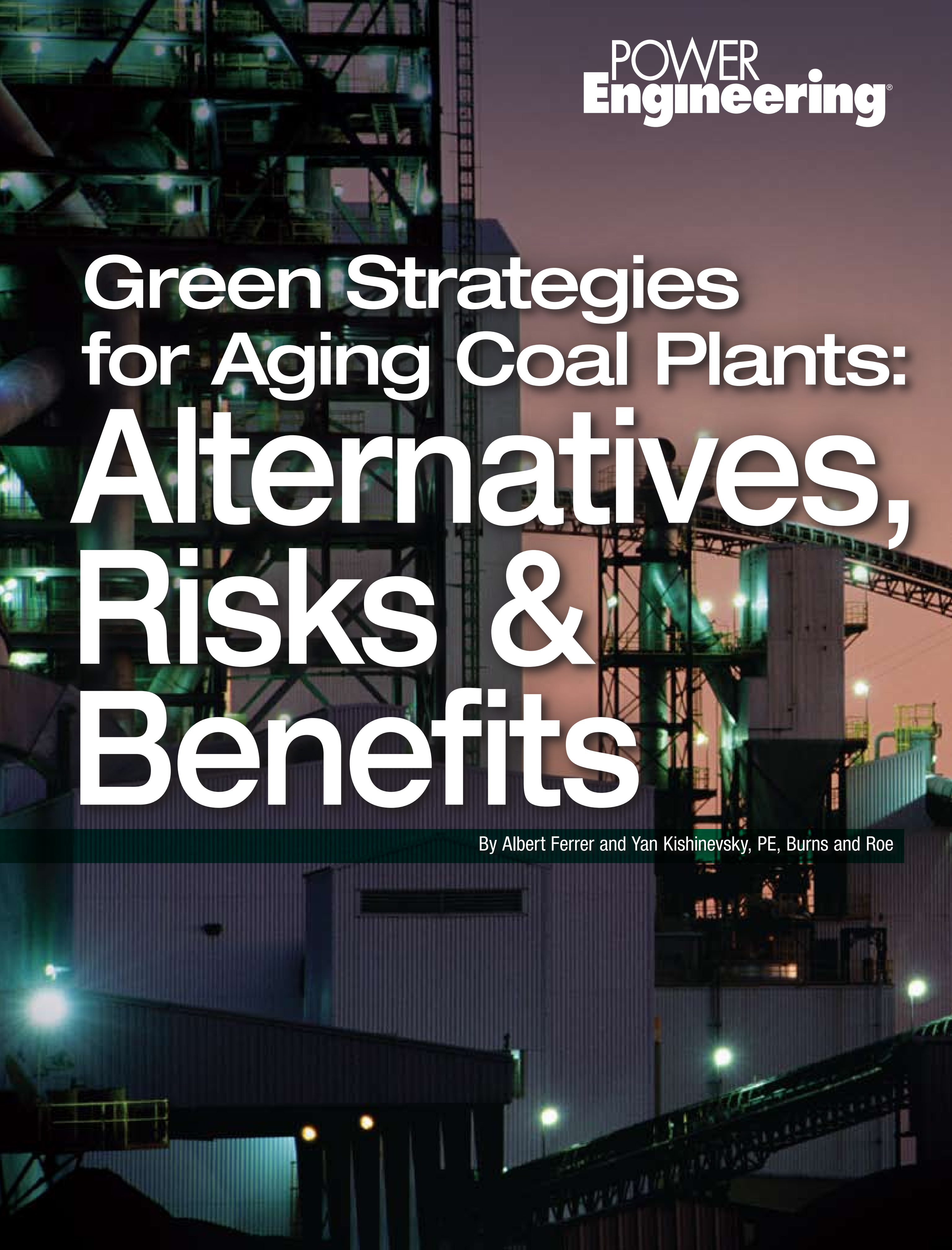


Green Strategies for Aging Coal Plants: Alternatives, Risks & Benefits

By Albert Ferrer and Yan Kishinevsky, PE, Burns and Roe

There are quite a few power stations less than 400 MW in size with successful and long histories of operation. Some of these, in fact, are considered "young" if they have operated for less than 40 years. However, they represent power plant technology developed at best in the 1960s, if not earlier.

This article identifies some of the challenges and discusses a variety of technical solutions available to power plant owners to keep these plants operating while reducing their carbon footprint. Most of the concepts discussed here have been available in the literature for many years. However, they deserve a "new look" if we are to address CO_2 reduction in a reasonable and cost-efficient manner.

As a whole, these power stations have been work horses for their owners while providing low-cost and reliable electricity to consumers. They continue to exhibit great flexibility in their original design by accommodating different load profiles and, in many cases, different fuels.

Much has been written over the past years on the subject of emissions and particularly over the past year on CO_2. It appears to be a reasonable assumption that the industry will see in the near future some sort of carbon trading, carbon tax or their equivalent.

Recent literature shows many articles calling for the application of new technologies to achieve carbon capture and sequestration (CCS) at new power stations. While some of these have been proven in the lab and others have been used on a smaller scale or for purposes such as enhanced oil recovery, the large-scale application of CCS to power plants is proving more difficult and costly. If these were to be applied today or in the near future (say, the next 15 years) on a large scale, it would require order of magnitude increases in electricity costs to consumers. Add to this scenario one that envisions taking our current gasoline-based transportation industry and shifting it to an electric transportation system and the demands for electricity will likely rise to heights we presently cannot imagine.

In the meantime, what can we do economically? What are the potential short term alternatives and associated benefits and risks?

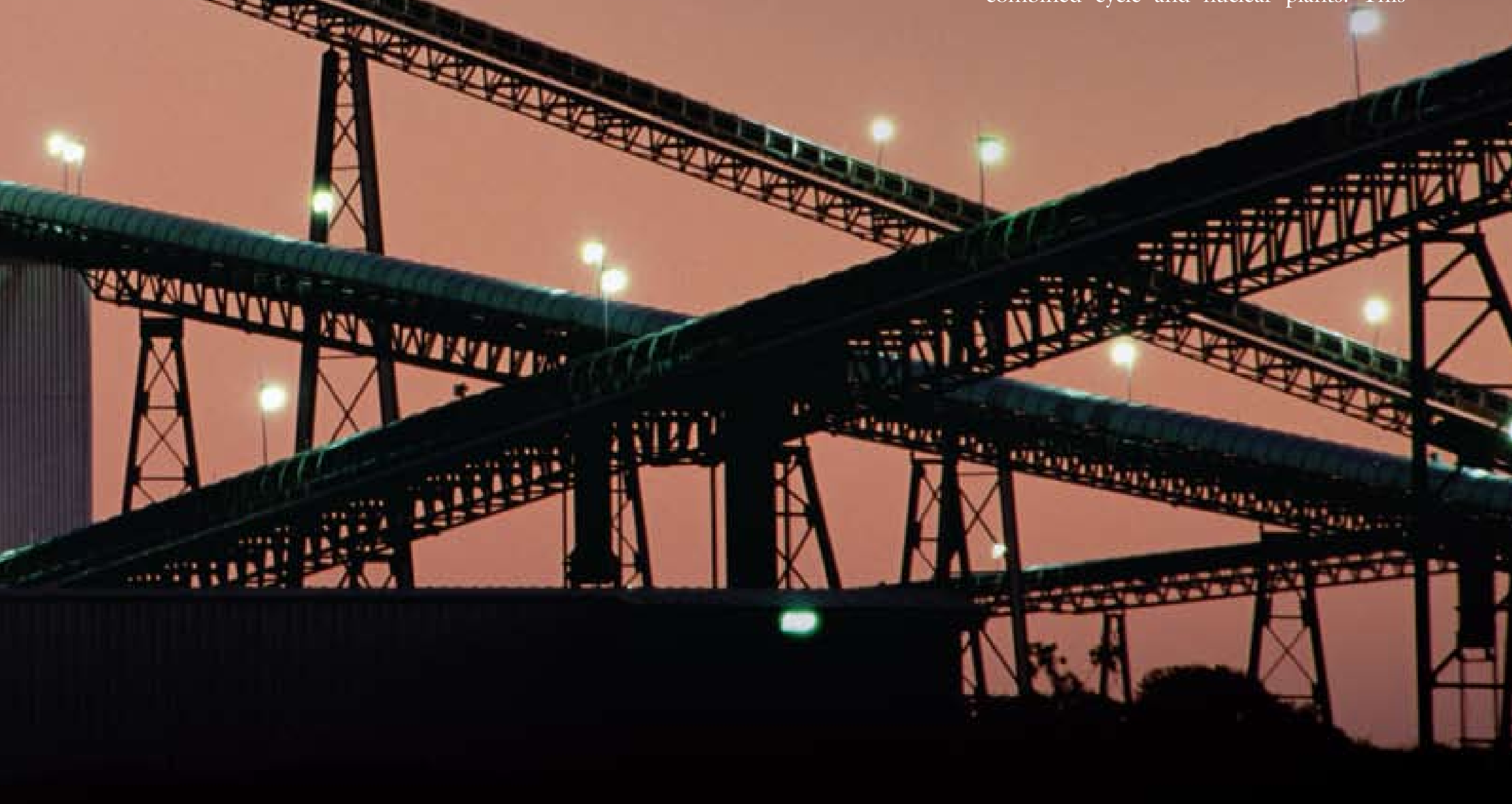
First some background. The fossil-fueled sector produces 39 percent of energy-related emissions. If nothing changes, it is projected to produce 42 percent by 2030 (88 percent of that share from coal). An additional 156 GW of coal based generation is projected to be added by 2030.

The fossil-fueled electric power sector in the United States is also the most CO_2-intensive in the U.S. energy economy. It produced 1,944 million tons of CO_2 in 2005 (82 percent of total emissions from the energy sector) and is projected to produce 2,927 million tons (88 percent of total emissions from the energy sector) of CO_2 in 2030.

In the U.S. about 50 pecent of the operating fossil fuel fleet, or about 400,000 MW, is coal-based. Around 300,000 MW of that capacity today is over 35 years old and requires modernization. Most older plants are either base-loaded or are used in intermediate load operation. Using this approximate figure, if we could reduce coal consumption by 5 to 15 percent, we could reduce carbon emissions equivalent to a reduction of 20,000 MW to 60,000 MW of coal-fired generation.

These older coal-fired units have an average power plant net efficiency of roughly 30 percent or less. Improving net power plant efficiency reduces the CO_2 discharge, fuel consumption (resulting in cost savings) as well as emissions, all by the same magnitude.

One obvious strategy to reduce carbon is to replace older plants with gas-fired combined cycle and nuclear plants. This



approach replaces the low-cost coal power with high-priced gas-fired power plants. Gas-fired plants still emit CO_2, however, but to a lesser extent. Nuclear power is a better longer-term solution. However, if ordered today, it may take up to 10 years to license and build. New nuclear power may be the best options since it eliminates the CO_2 emissions altogether and maintains low power costs due to its own low fuel costs and economy of scale.

The downside, of course, is that it may take eight to 20 years to see a large number of nuclear plants built. What can we do in the interim? A few major approaches can be taken.

Biomass Co-firing

Making use of biomass in the fuel mix is a sure way to reduce carbon, since biomass is generally accepted as a carbon-neutral fuel. Co-firing can be done in most power plants (up to 4 to 5 percent co-firing) with no significant degradation; an even larger percentage could be achieved depending on the boiler design. Boiler technology could be upgraded to a bubbling bed configuration or the plant could be repowered to accommodate circulating fluidized bed combustion. These measures would allow bringing the fraction of biomass in the fuel mix to around 20 percent.

Of course, a sustainable source of biomass is required. This can be achieved by engaging in sustainable forestry practices and by growing energy crops with genetically modified species of willow and poplar, for example.

Renewable Technologies

This approach envisions using renewable technologies in existing coal power plants; for example, biodiesel as fuel in auxiliary boilers and as back-up fuel for main boilers. Biodiesel is considered both a renewable fuel and carbon neutral. With appropriate and expeditious air permit changes it could be applied quickly as long as prices remain stable.

Among coal plants in some geographic locations (such as in North Africa, Greece, Arizona, Nevada, California and New Mexico) solar power (and in particular, concentrating mirror technologies) could be used to pre-heat air or feedwater before it enters the boiler thus reducing the amount of fossil fuel needed to generate steam. This type of renewable application is much less costly and more efficient than generating power directly from solar sources.

This same preheating concept also could be used in conjunction with adding biomass boilers to a coal power station to preheat air and/or feedwater. This approach would lower the carbon content of the emissions.

So-called hot wind box repowering is a potential fit here, too. While not a renewable energy source, per se, gas turbine exhaust (waste heat) is used to bring hot air into the boiler, which has been appropriately modified to accommodate this configuration. The approach reduces the need to burn at least a portion of the coal.

Repowering with More Efficient Boilers and Turbines

The repowering approach consists of changing the boiler and "repowering" the power station using newer boiler technologies, which have higher efficiency and better emissions profiles. In a repowering, the new technologies could allow co-firing of up to 20 percent biomass. This would improve net efficiency by reducing the coal consumption while producing the same megawatt output. Every 2 percent cycle efficiency improvement results in a 5 percent reduction of CO_2 emissions. Such a change in boiler technology could be done in combination with turbine improvements and changes to variable speed drives in major components which could further improve efficiency.

All the major boiler vendors offer models with improved efficiency and performance. Recent advances by boiler vendors in CFB technology in the 150 MW to 300 MW range indicate that they are viable technologies to consider.

However, some recent attempts to modernize and improve performance by power plant owners have been met with lawsuits, which further increase the costs of these efficiency improvements. If this alternative is followed, it must be accompanied by government policy makers passing laws necessary to encourage or incentivize improved efficiency in the existing coal fleet.

There are various areas we can identify to effectively improve efficiency:

Instrumentation and Controls

In a recent article in *Power Engineering* ("Small-Buck Change Yields Big-Bang Gain," July 2007) we discussed the various ways that control systems could be "tuned" such that 4 percent to 7 percent improvement in efficiency was realized by making the boiler/turbine generator work at their optimum operational control points with an investment of less than $200,000.

Recent literature indicate that implementing the "intelligent power system" where instrumentation and control systems are given "intelligence" to conduct performance analyses and process monitoring and optimization functions can increase cycle efficiency. By applying advanced control technologies, these systems are also able to perform analysis for optimizng boiler and turbine operations at various loads to maximize plant efficiency. In this manner, the plant operator obtains a smoother operation with as much as 50 percent fewer trips, a greater efficiency (up to 5 percent to 10 percent improvement) and a positive increase in his/her balance sheet.

The entire power plant control philosophy and instrumentation array should be reevaluated, including sensors, controllers and actuation devices. These are used to measure the values of relevant parameters and control systems, which maintain the optimum operation of the power generation components such as boilers and turbines. The average life of a modern I&C varies from 10 to 15 years for PC-based systems and 15 to 20 years for proprietary distributed control systems. Cost of upgrading I&C in coal-fired plant is estimated to range from $1 to $6 million.

Power Cycle Mechanical Equipment

One alternative is to increase turbine efficiency by improving blade design and configuration on the back end of the steam turbines and by installing denser rotor packs. This could add as much as 3 to 5 percent to cycle efficiency. Such rotor upgrade and replacement is estimated to cost $25 to $30 million.

Adding heaters to the existing power cycle or replacing them (in most older power plants there is room to do so) and eliminating steam leaks in the typical older coal power plants would improve efficiency by as much as 3 to 5 percent depending on the condition of the existing heaters. Individual heater replacement cost can run between $8 and $10 million depending on the size of the power generating station.

Adding steam turbine-driven feed pumps where none exist or improving existing pumps with more modern designs can also add 2 to 3 percent to efficiency at a cost of $1.5 to $3 million. And replacing old aux boilers to accommodate more efficient designs and renewable fuels, or eliminating the aux boiler altogether, could add 4 to 6 percent efficiency to the overall net cycle.

Electrical Systems

The use of variable frequency drives for boiler feed and condensate pumps, induced draft fans and forced draft fans can provide precise speed and load control with potential increased efficiency at reduced loads of up to 2 percent. The actual auxiliary load savings will vary with plant load and duration. This load savings means increased net efficiency for the plant at a time when fuel utilization may not be optimum.

Another approach to the electrical house load is to conduct a study of the auxiliary load and reduce it to the lowest level possible by changing HVAC systems to more modern configurations. This alone could add a few percentage points in efficiency to the power cycle.

Other Improvements

Various other improvements could be made to the power cycle to increase the overall cycle efficiency by as much as 4 to 6 percent. These could involve:

- Minimizing excess air and improving combustion control
- Installing cooling tower film pack
- Installing on-line condenser cleaning.

Additionally, the revision in current regulations to allow once-through cooling systems could also substantially decrease CO_2 emissions by improving cycle efficiency.

Cogeneration is a sure way to increase overall cycle efficiency and reduce CO_2 emissions without penalizing performance significantly. This technique could increase efficiency by as much as 15 percent to 25 percent. If low-pressure steam can be used by an industrial customer, the overall cycle efficiency improvement can be over 40 percent.

All the above concepts can be applied to the existing fleet of North American coal plants, but the economic incentives must exist to make this happen. While the increase in fuel prices helps, additional economic incentives are required, such as renewable credits for every dollar spent in improving power plant efficiency. In that sense, the incentives would be much like demand-side management incentives to encourage consumers to reduce consumption.

If the techniques described above are to be applied to a deteriorated coal plant, then the costs will be high and the benefits may not be fully realized. In that case the power plant owner must decide how much of an investment in the plant he or she is willing to make. In some cases, the total benefit in improved efficiency may not be additive.

In general, however, the size of the investment to achieve these CO_2 reductions is but a fraction of the cost being discussed for CO_2 capture and sequestration. What's more, the investments outlined above can be implemented over the next few years. Obviously, a thorough evaluation of each power plant facility for opportunities to improve efficiency should be considered as a minimum before large expenditures are made in carbon capture and sequestration.

Eliminating as much CO_2 before it is released backed up with a program to construct new nuclear generation will get us over the next 50 years. The existing fleet of coal-fired power plants can continue to play an important—and greener—role in achieving that goal. **pe**

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