

## ***Retrofit Programs Increase Generation Efficiency and Decrease CO<sub>2</sub> Emissions***

### **Reducing CO<sub>2</sub> Emissions from Existing Units**

***Prior to the commercial availability of CO<sub>2</sub> capture and sequestration technologies, the best option for existing plants to reduce CO<sub>2</sub> emissions is through the retrofit of efficiency-increasing technologies.***

While new, higher efficiency coal-based power plants offer lower carbon dioxide (CO<sub>2</sub>) emissions per unit of electricity generated, complete replacement of existing generating units is not economically feasible because their lifetimes are typically greater than 40 years. Therefore, replacement costs would be prohibitive. Also, less efficient subcritical pulverized coal (PC) units play a key role in meeting base load electricity demand, and taking them out of service for replacement would have significant impacts on the availability and reliability of electricity nationwide.

There are 320,000 MW of coal-fired generating capacity in the U.S., provided by 1,100 generating units. They are of various types, sizes, and ages. Fortunately, there are many technical methods to gain modest efficiency improvements in many of these units. These methods range from combustion improvements to enhanced heat transfer in boiler components to moderate rebuilds of specific boiler sections. They involve modest capital expenditures, incurrence of variable expense, or both.

The technical modifications that have potential to increase plant efficiency are discussed in the following section. These options are commercially available for small and large-sized generating units, unlike CO<sub>2</sub> capture and storage (CCS) technologies.

### **Efficiency Improvements**

Improved efficiency reduces CO<sub>2</sub> emissions by reducing the amount of fuel required to generate a given amount of electricity. A two percentage point gain in efficiency provides a reduction in fuel use of about 5% and a similar reduction in CO<sub>2</sub> emissions. Improved efficiency can also provide similar reductions of other pollutants regulated by the Clean Air Act, and reduce water consumption.

While not as dramatic in scale as building new higher efficiency power plants, small gains can be made across the fleet of existing plants through component upgrades, as well as operations and maintenance activities. These improvements will be very specific to a given unit, but generally can lead to improvements resulting in reduced CO<sub>2</sub> emission rates. As an example, the average generation efficiency in 2005 for fossil-fuel steam generating power plants was 33%, emitting 2,450 million tons/year of CO<sub>2</sub>. If the national average heat rate (a measure of efficiency) was reduced by 100 Btu/kWh (the lower, the better, for heat rate), CO<sub>2</sub> intensity would be reduced by 1%, with a 29 million ton/year reduction in CO<sub>2</sub> emissions.

Improvements in efficiency are available with commercially available technology and are segregated into several performance areas of a coal-fired boiler: combusting the coal, transferring heat to the steam, reduction of gas temperature leaving the boiler, facilitating steam turbine performance, and auxiliary equipment efficiency. All the improvement areas stated above for the existing coal-based fleet are for maintaining initial design performance of all areas of the generating unit, from decades of real-world experience with numerous changes in coal quality, water quality and electricity demand .

Applicability of any of these upgrades to any of the 1,100 currently existing units is very site-

specific. The technical solutions include in general:

- Steam turbine improvements, including upgrades of blades and control valves.
- Cooling tower and surface condenser upgrades and programs to reduce cooling water temperature and turbine back pressure, minimizing air leakage into the exhaust steam.
- Variable speed drive technology for pumps and for motors to reduce power consumption.
- Air heater upgrades to increase heat recovery and reduce leakage.
- Advanced control systems to optimize temperature, pressure and flow rates of coal, air, steam and water.
- Programs to maintain boiler cleanliness when firing lower grade coals.
- Coal drying (cleaning, drying, blending, granulation, or chemical treatment).

## Specific Technologies to Improve Efficiency

For an existing coal-fired unit, the potential efficiency improvement attainable varies by unit. The biggest factor is the existing baseline level e.g., if a plant was previously focused on optimizing efficiency, there will be less room for improvement. Conversely, if attention to efficiency was not as high, substantial gains may be able to be made, thereby providing low-cost reductions of CO<sub>2</sub> per unit of electricity generated.

Summarized below are technologies for efficiency improvement, classified in terms of

three nominal levels of effort which have been termed “minor”, “average” and “major”.

1. **Minor.** Technologies in this category cost up to \$1 million, and typically yield a heat rate improvement of up to 1% on a stand-alone basis. Examples include:
  - Combustion tuning (e.g., low excess air operation, fuel/air balancing, mill performance improvements).
  - Reduction of steam side losses, (e.g., turbine steam seals leakage, feedwater flow nozzle calibration, and low-pressure turbine efficiency measurement).
  - Installation of efficiency monitoring hardware, along with efficiency awareness courses for plant operators.
  - Implementation of on-line performance monitoring system.
  - Chemical addition to surface condenser cooling water for cleanliness factor improvement.
  - Deployment of chemical addition to increase ease of ash removal from boiler and superheater tubes.
2. **Average.** Technologies in this category cost up to \$10 million, and may yield a heat rate improvement of about 1%, depending on the application. Examples in this category include:
  - Implementation of commercial software-based optimization systems.
  - “Intelligent” sootblowing systems.
  - Flame diagnostic systems (such as the EPRI Flame Doctor)

- Utilization of advanced (near commercial) sensors for mapping of critical gas species (CO<sub>2</sub>, O<sub>2</sub>)
3. **Major.** Technologies in this category can cost well in excess of \$10 million, but may yield a heat rate improvement of 1-2 percent or greater. Examples of items in this category include:
- Major modifications or upgrades to condensers (e.g., to improve back pressure)
  - Major modifications or replacement of pulverizers (e.g., to improve particle size distribution)
  - Installation of higher efficiency large motors (e.g., circulation water pump motors) and/or variable speed drives
  - Cooling tower optimization (e.g., reduced cells in service during winter operation)

## Combustion Improvements

Combustion improvements burn coal more efficiently. Greater energy is released from the coal, while utilizing less combustion air, thereby producing more electricity per unit of coal.

Means of combustion improvement that are categorized as a minor expense include tuning burners for maintenance of optimal coal/air ratios, thereby minimizing combustion air use (excess combustion air carries heat out of the stack). “Intelligent” control systems are available that analyze completeness of combustion in the boiler, and also adjust firing parameters automatically based on “learning” the optimal operating parameters for changing furnace conditions. The “major” expense category includes coal pulverizer upgrades. The function of pulverizers is to reduce coal size to make the coal easier to burn. Improvements in coal grinding and particle size distribution prevent unburned combustibles, thereby increasing efficiency. The consistency

of pulverized coal is similar to that of talcum powder.

## Steam Side Changes to Improve Efficiency

The basis for efficiency of the steam cycle component of electricity generation is the difference between the temperature of superheated steam entering the steam turbine and the temperature of the exhaust steam leaving the turbine. There are several means of maintaining design superheat steam temperature and optimizing removal of heat/expansion of steam leaving the turbine.

Turbine blading and steam path upgrades, including turbine control valve upgrades, can result in more efficient use of the energy from steam produced in the boiler. This is particularly true with the boilers that frequently cycle to lower loads. Upgrades to the cooling tower heat transfer media may be applicable on certain units, which would yield lower circulating water temperatures. Lowering condenser temperature reduces back pressure, and increases turbine efficiency.

Variable speed drive technology can be applied to pumps and fan motors. By only running large pumps and fans at speeds necessary to support a given load, auxiliary power consumption is reduced. Air preheater upgrades can be applied to many older units. Modern heat transfer media and seal upgrades increase heat recovery and reduce leakage, resulting in better use of heat and energy.

In addition to upgrades in specific steam-side components, heat transfer media in the heat transfer sections, and component motors, programs to maintain cleanliness of heat transfer areas also increase cycle efficiency. Mechanical and chemical programs are commercially utilized to maintain greater cleanliness of steam generating tubing and super heater tubes, with respect to the insulating effects of coal ash. (This is particularly important as switching away from the coal for which the boiler was initially designed has become more prevalent for SO<sub>2</sub>, NO<sub>x</sub> and cost-related reasons).

Similarly, there are mechanical and chemical programs that exist for maintenance of cleanliness in the surface condenser – the component that converts low pressure steam exiting the steam turbine to water for reuse in the boiler. This is the largest point of heat loss in the steam cycle. Therefore, some level of efficiency improvement can be available on many boilers.

The items listed above are a sampling of options that can offer measurable increases in unit output and/or reductions in CO<sub>2</sub> emissions. In a recent study by American Electric Power (AEP), presented to the Asia Pacific Partnership in September 2006, AEP estimated these types of upgrades would yield reductions of more than 3.5 million tons of CO<sub>2</sub> per year across its generation fleet. Efficiency upgrades also can be implemented in conjunction with retrofit of emission control systems.

In addition to CO<sub>2</sub> reductions, optimizing efficiency brings significant coal cost savings. In the examples above, and assuming a fuel cost of \$2 per million British thermal units, the plant also would realize \$700,000/year in fuel

savings for the same 1 percent heat rate improvement.

## Conclusions

By retrofitting commercially available technologies and equipment, improvements to efficiency can be made to existing coal-fired generating units. A key result of these efficiency enhancements is a reduction in the amount of coal burned per unit of electricity generated, which results in a direct reduction in emissions. The advantages of these retrofit programs are as follows:

- For the existing coal-based generating fleet, increasing supply (generation) side energy efficiency is a key strategy for low-cost reductions of CO<sub>2</sub>.
- Many technologies are commercially available today to provide modest gains in generation efficiency.
- Millions of tons of CO<sub>2</sub> per year can be realized from even single digit improvements in efficiency.

*As a public advisory committee to the Secretary of Energy initially chartered in 1984, The National Coal Council has compiled over 30 reports at the Secretary's request on numerous issues affecting coal and U.S. energy policy. The factual information in this paper, and the conclusions based thereon, are drawn from these studies and the documents used to compile them, all of which have been submitted to the Secretary of Energy.*